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ALUMINUM: ITS MANUFACTURE AND USES FROM AN ENGINEERING STANDPOINT.

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Defining the science of engineering as the knowledge that has been accumulated of the relations to one another of force, matter, space, time and motion, and the practice of engineering as the art of applying this knowledge to the conversion of the materials and forces of nature to the use and convenience of man, we see that a broad field has still been left for the consideration of aluminum in the limiting clause in the title of the lecture to be given to you this evening.

Aluminum is now being made throughout the world upon a commercial scale only by processes of electro-deposition from fused electrolytes. In this country, the Pittsburgh Reduction Company and the Cowles Electric Smelting and

Aluminum Company are the only concerns manufacturing commercially and furnishing the American market with aluminum. In Great Britain, the Metal Reduction Syndicate, Limited, a branch of the Pittsburgh Reduction Company; and in Switzerland, the Aluminium Industrie Actien Gesellschaft, manufacturing at Neuhausen, using the water-power of the Falls of the Rhine; and in France, the firm of Bernard Brothers, now building a works at St. Michaels, and operating the Minet process, are, so far as the writer's knowledge goes, the only manufacturers now whose metal is met in the competition of the world's rapidly-growing market for aluminum. These statements need to be made preliminary to any considerations of the purity or other qualities of the commercial aluminum of the markets of the present day, for the reason that manifestly it will not be fair to take into consideration in treating of the commercial aluminum of to-day, the impure products made only on a small scale by the great number of processes being experimented upon, and by the many people working upon "The Aluminium Problem," as one of your lecturers, Prof. Richards, has pleased to call the present state of the art regarding the metal. The "problem" of extracting aluminum from some of its compounds which was first solved by Wöhler, in 1827, and later more completely by Deville, in 1854, has now been solved so many times and in so many ways that the task need hardly be dignified with the rank of a "problem" to-day. It takes very little skill with our present knowledge in the metallurgical arts to produce an impure grade of aluminum, as evinced by the many charlatans who are endeavoring to delude the public with their experimental exhibits and brilliant pages of prospectus or newspaper effusions. In the judgment of your lecturer, the aluminum "problems" of to-day are not so much the ways to produce the metal *most cheaply*, as the ways of utilizing the metal in the arts.

In the first of these problems, with great respect and with due deference to their opinions, I disagree with those who have spoken before me from this platform, in their expectation that cheaper methods of production are forth-

coming. I am modestly, but firmly, of the opinion that the aluminum problem of the cheapest method of production has been practically solved in the electro-deposition of the metal from fused electrolytes, and that only in details will this method be improved or this part of the aluminum problem be better solved.

I am confident that the aluminum problem of *quality*, as determined by the purity of the metal, has been solved, and that upon a practical commercial scale, too, by several of the later methods of manufacture. At the works of Pechiney & Co., in France, from a date at least as far back as 1882, to my personal knowledge, M. Henri Brivet, their managing director, was enabled to manufacture regularly, by taking the utmost precautions and with carefulness and skill in manipulation as well as in all details of the Deville sodium process of production of aluminum, metal of over ninety-nine per cent. purity, an achievement, which, with the knowledge and state of the art of aluminum manufacturing then existing, and with the inherent difficulties of manufacturing pure aluminum by the sodium process, was worthy of the highest praise.

The impurities of the sodium-made metal are about one-half silicon and one-half iron. Both the Aluminium Company, Limited, of Oldbury, and the Alliance Aluminium Company, of New-Castle-on-Tyne, England, made metal and placed it upon the market in 1887 and 1888, of over ninety-nine per cent. purity; and Richards, in his work on *Aluminum*, edition of 1890, p. 246, refers to aluminum made by Grabau by a modification of the sodium process, in 1888, having 99·80 per cent. pure aluminum.

Both the Neuhausen concern and the Cowles, as well as the Metal Reduction Syndicate, Limited, of Patricroft, Lancashire, England, and the Pittsburgh Reduction Company, find no trouble by the electrolytic process in producing regularly metal with less than one per cent. of impurity. Indeed, the best results in quantity of output and regularity of working, and therefore in economy of manufacture, are when producing the purest aluminum, and it only requires further development of the manufacture of the aluminum

oxide used as the ore and of the carbon anodes—matters which are perfectly practicable and possible—to obtain almost absolutely chemically pure aluminum by the electrolytic methods now in use. The Pittsburgh Reduction Company have made a good many tons of aluminum of over 99·90 per cent. purity; and I take pleasure in showing you and leaving for your museum a number of little ingots of aluminum containing no iron, copper or lead, and only eight-one-hundredths of one per cent. of silicon, having 99·92 per cent. pure aluminum, by the results of our chemist, Mr. J. O. Handy. With these achievements accomplished, I claim that the problem of quality of the metal as evidenced by its chemical composition has been solved, and solved with fully as much perfection as is the case in the metallurgy of any of the other metals. For with the same amount of care and precaution necessary to produce the so-called chemically pure metals of the markets to-day, by the electrolytic process equally pure aluminum can be produced, and in regular commercial practice aluminum is now being produced as pure in chemical composition as any of the other metals. I make this statement with care, and I think advisedly, being aware that other authorities, for whom I have great respect, have recently written to the contrary. The standard of purity of product obtainable in commercial aluminum having already been established by the processes now extant, and the advantages of the pure metal having become apparent, quite surely any new process to be successful in its competition for the market will have to produce metal of equal purity; a task that will in itself condemn many possibly competing processes. As aluminum is a much more difficult metal to reduce from its ores, under ordinary conditions, than is silicon or iron, almost any reagent or set of conditions that will result in the production of metallic aluminum, will alloy with it any iron or silicon that there may be present in the reagents used. This necessitates the materials used being almost chemically pure from silica, iron and other more easily reducible metals—a condition that will add fatally to the expense of many possible processes. The only alternative

that seems to me possible is a method yet to be devised of cheaply purifying the metal alloyed, with these substances. In fact, in this possibility of obtaining the metal alloyed and impure on a large scale and in a cheap way, and then purifying the aluminum, or a method of manufacture of the aluminum as a by-product of other operations, to my mind rests the only possible competition in process to the electro-deposition from a molten electrolyte.

In the economical reduction of the ores of most metals, one of the most difficult problems to be solved has been the wastage due to oxidation, volatilization or the solvent action of slags, or the impartial reduction or separation and collection of the metal, and its consequent waste in the scoria or refuse product. There are very few metals reduced to their pure state without a wastage of at least ten per cent. In the manufacture of aluminum as practised by the Pittsburgh Reduction Company, there is practically no waste whatever, the waste problem having been by the Hall process entirely solved.

I have already, in a previous lecture in February, 1891, before the Boston Society of Arts, stated that the cost of manufacture under the most favorable conditions with water-power and large output, would be approximately twenty cents per pound. Nearly one year's experience and careful study of the matter leads me to reiterate the statement then made, and to prophesy that the ingot metal will be made by the Hall process within the next few years at *a cost* of between eighteen and twenty cents per pound; the items of cost being about one-third for the ore, one-sixth for the expenditure of other materials than ore, one-third for the electrical current expended, one-twelfth for labor and superintendence, and one-twelfth for general expenses, interest and repairs.

Analyzing these items of cost, the ore will probably be the greatest item of expense in any successful process, and surely the oxide alumina is not only the richest and most easily prepared pure ore, but will prove one of the cheapest, if not the cheapest, of compounds from which to extract the metal. Any methods of cheaper production of alumina

from clay or other more abundantly found mineral than bauxite (the hydrated oxide, containing from fifty-five per cent. to sixty per cent. alumina, and with less than ten per cent. silica and iron, the remainder being water), which can be laid down in Pittsburgh now in almost unlimited quantities at less than one-half cent per pound, will be equally applicable to the electrolytic as to any other process. Quite surely no difference here in the art will make an insurmountable barrier of cost for the electrolytic processes now in use to compete against. The expenditure for other reagents than the ore, for carbon and for chemicals, is now less than five cents per pound, with the Pittsburgh Reduction Company, and in the estimate can fairly be reduced to three cents per pound for a large plant, with most favorable arrangements made for its supplies. In the item of electrical power, there certainly may be room for a curtailment of cost; but even should this expenditure of electrical power be lessened one-half, or entirely done away with, heat alone being substituted as the energy for reduction of the ore, it will be difficult to conceive of a method that would not require a cost of at least one cent for this heat, which would be a saving perhaps of four cents per pound upon this item of electrical power. However, I feel confident that should such processes be devised, the increased expenditure for chemicals and other reagents, besides the amount quoted as necessary for the Hall electrolytic process, will nearly, if not quite, counter-balance the saving in electrical energy expended in the Hall process.

In the items of labor, superintendence and general expense, interest and repairs, there may be a small saving made by a process yielding metal more rapidly than by the comparatively slow electrolytic process.

I would, however, here call attention to the fact that our present experience leads me to believe that the items of labor and superintendence will quite surely be reduced to between two and three cents per pound of metal produced, and the amount required for general expenditure, interest and repairs to no larger than an equal expenditure, when the metal is made upon a very large scale. Again, these

are necessary and inherent items of cost of any method of manufacture and the amounts that can be saved here by other possible means of manufacture, in my judgment, will prove very small indeed, surely not more than three cents per pound at greatest—an amount which I grant might, at some future time of competition, be a fatal one to the higher cost parties, but would not be such an amount as to lead to such startling changes in the selling prices of the metal, beyond what can be done by the electrolytic manufacturing interests, as one would be led to believe by the prophets who have gone before me. With the cost of manufacture being the ore at six cents per pound of metal made, and subject to almost any possible lowering of rate applicable to any other process, the power and materials used at eight cents, and the labor and all remaining expenses at between four and six cents per pound—cost items that I believe will be obtained gradually within the next few years by the electrolytic methods of production, I do not believe that there will be other methods devised to successfully compete with their totals of cost per pound. The average energy expended per pound of metal produced by the Pittsburgh Reduction Company is about twenty electric horse-power hours, or each electric horse-power hour of energy exerted upon the electrolyte yielding about twenty-two and seven-tenths grams of metal. Each month, by new experience, we are adding to this efficiency, and we confidently hope to make a gain of at least ten per cent. upon this record soon; and I shall not be satisfied until this gain in efficiency shall reach at least twenty-five per cent. over present rates.

Our compound engines have a record of two pounds of coal per indicated horse-power hour, and with a twenty per cent. loss of potential in conversion of indicated horse-power into electrical—an estimate that is very liberal—we have twenty-four indicated horse-power hours per pound of aluminum produced, or an expenditure of forty-eight pounds of coal, which costs us eighty cents per ton at our works, or an expenditure for fuel of less than two cents per pound for the aluminum produced. Of course, to this has

to be added labor, water (which we pump direct from the adjacent Allegheny River) and repairs; items which count up considerably upon a plant of only 600 horse-power; but with a large plant will bring the cost for power per pound of aluminum very low, and at a rate which will compare, especially if triple expansion and condensing engines are made use of, very nearly equally with the cost of the best water-powers. With water-powers, of which there are several in blocks of over 1,000 horse-power each, throughout the country, available at rates of from $8 to $15 per horse-power per annum, we can reckon on the cost of the electrical energy per pound of aluminum at between two and three-quarters and three cents per pound of metal made. Undoubtedly, the splendid power to be developed at Niagara will prove one of the best in the world for the manufacture of aluminum.

At these rates, a margin of nearly 100 per cent. is allowed in the estimate given above for the cost of the electric power, for a plant manufacturing aluminum by the Hall process under the most favorable conditions.

I do not, however, much fear the solution of this portion of the "aluminum problem," adversely to the interests of those of us who are engaged in the electrolytic method of its manufacture. I assure you that I do not thus confidently assert the courage of my convictions without a reason therefor. I have recently read over the historical portions of articles on aluminum in the world-famed *Journal of the Franklin Institute*, and with trepidation noted that it was possible to read the epitaph of all the methods of manufacture which started before the present ones of electro-deposition from molten electrolytes; many of them in the light of their day with even more of bright prospects of financial and metallurgical success than those now extant. I have noted that while Prof. Henderson was reading his able article before your Institute, in October, 1888, on aluminum, in which he speaks of the improved Deville sodium methods as the ones *de facto* supplying the world's aluminum of that day, the metal was then being regularly made by a cheaper method, and a commercial works within

a month more were in operation, manufacturing upon a larger scale than ever before, by the electrolytic method that was to entirely supersede the improved sodium processes. Perhaps a similar fate hangs over this paper and its author. I am aware that precedent, as well as popular (and to a considerable extent, scientific) opinion is against me, and I can assure you that it would take much less courage for me to acknowledge the probability rather than to assert the improbability of a cheaper and better process, yet I am constrained to take the position that I have, with the hopes of turning the inventive and skilled, as well as the popular attention, to the fact that the next great source of cheapening aluminum will be a large demand for the metal, at present prices, sufficient to warrant outlay in plant to very greatly increase the capacity for manufacturing the metal. Aluminum will not be manufactured by any process at much less than at present, nor will it be sold at much lower rates, until the output be measured in tons, and not pounds, per day. The lowering of the market price of aluminum in the future will be gradual, and will be directly proportionate to the decrease in cost of manufacture, due to increased capacity of the manufactories.

Just as the wide-spread acceptance of inaccurate and misleading information regarding the properties of the metal hindered the development of the uses of aluminum in the arts, so at present the wide-spread forecasts of the metallurgical prophets, that the stars of new and much cheaper processes of manufacture are above the horizon of their horoscopes, without so much as vouchsafing us any tangible reasons therefor, are equally hindrances in that they discourage the expenditure of capital necessary to develop the manufacture of aluminum upon a scale sufficient to materially reduce the present manufacturing costs of the metal. The many brilliant new projects backed by scientific experts for manufacture of aluminum at wonderfully low costs, which flash out in the newspapers like meteors in the sky, and die out as rapidly, do much not only to hinder capital entering legitimate aluminum industries, but in deterring consumers from using or carrying

any stock of a metal whose selling price they are led to believe may any day be reduced very much more than any possible gain their fabrication upon it may be to them.

In my judgment, the aluminum problems of by far the greatest moment yet remaining to be solved are in connection with the development of the uses of aluminum in the arts. Much has already been done in this matter, the demand for the metal increased tenfold over any previous year in 1891, yet very much more remains to be done. Undoubtedly much has yet to be developed in details in the economical production of aluminum; probably very few realize that more than your lecturer. At the same time, the problems involved in the development of the uses of aluminum in the arts have been under-estimated, and have not received the intelligent consideration that the importance of the subject warrants. The world has been centuries learning to use other metals; we have a right to expect more rapid development with the increased general knowledge of to-day, yet it will at best take time to open the entire field that the metal is destined to fill. Within the past ten years, there have been two popular widely-spread ways of solving this portion of the "aluminum problem," which are superficial, erroneous, and a hindrance to the true solution of the problem; the first assuming properties for the metal that it did not possess, proclaimed that aluminum would, as soon as it could be produced in sufficient quantities, replace all the other metals in the arts, not only for the special purposes where the higher grade metals are now used, but also for structural and building purposes to replace iron and steel; the second view of the subject (the natural reaction from the first erroneous one has become current within the past year or two, as the people began to use aluminum and found their ideals regarding it shattered) is to the effect that the metal has little or no use in the arts.

The reasoning for the first popular erroneous answer to the problems involved in the development of the uses of aluminum in the arts, was that aluminum was by far the most abundant of all the metals in its distribution in the earth's crust, and *consequently* should be the cheapest. Confusing

the comparison of strength of materials, section for section with equivalent weights, forgetting to take into account its low elastic limit and modulus of elasticity, or modulus of resilience, or its lack of rigidity under compression strains or its natural softness; but noting that the metal withstood the ordinary atmospheric and other usual conditions of corrosion with considerable efficiency over other metals commonly used in the arts, the enthusiastic conclusion was reached that we were rapidly leaving the "steel age" as we had the "iron age" before it, and were advancing upon the "aluminum age," "where this wonderful metal should supersede all others for almost all the uses of mankind." It is surprising that some of the hopeful ones did not propose to mould up the clay banks into buildings and railroads and other useful contrivances, and turn on the electric current and produce the aluminum structures *in situ*.

As instances of the second view of the case that I am sorry to say has become quite fashionable of late, as shown by the frequent publications in trade journals, a writer in a recent German publication disappointed in his ideals regarding the solubility of the metals in acids, and finding that aluminum could not be used as a substitute for platinum in acid stills, immediately jumps to the conclusion (and publishes his conclusions broadcast) that the metal is entirely unsuitable for culinary utensils, seemingly forgetting that cooking operations are not conducted in muriatic, nitric, or even in sulphuric acids, as dressings or gravies, and not considering it necessary to investigate the action of these acids or their salts upon the metal in quantities, and under conditions similar to those the metal would in any likelihood be subjected to in actual use in culinary utensils.

Another writer has gone through a long list of experiments, heading his table of results "Solubility of Aluminum in Acids," using aluminum *foil* and finding that in from two to four days the foil was dissolved in from one to ten per cent. solutions in water or many organic acids, such as formic, acetic, butyric, lactic, tartaric, citric, oxalic, palmitic, stearic, gallic, salicylic, carbolic, boric, etc., he wisely proclaims that these results show that this

metal is unfit for canning materials, cooking utensils or any chemical laboratory purposes. This writer forgets to investigate the differences between foil and thicker plates before drawing his conclusions, nor did he inquire as to the action of these same reagents upon equally thin foil sheets of other metals, now used for the operations he describes. Had he done so, he would have found that in the sections used in utensils of other metals, aluminum withstands the action of all the reagents mentioned as well as do the metals now in common use; and as for the action of ordinary solutions on thin foil, tin, iron and copper are fully as rapidly acted upon as is aluminum. Aluminum has neither taste nor odor, nor are its salts (in small quantity) especially poisonous, as are the salts of other metals now more commonly used.

Aluminum is not much more acted upon than is tin, copper or silver by salt water, and even by such solutions in vinegar as the metal is liable to be subjected to in ordinary culinary vessels. The salts of tin or copper thus dissolved are very poisonous; but not only are the aluminum salts that are formed less in amount, but the acetate of aluminum formed resolves itself on boiling into either an insoluble subacetate or into pure alumina, neither salt having either taste or injurious toxic action. For these reasons, quite surely aluminum will have a large future for cooking utensils.

Aluminum cooking utensils have been used in my own home for the past two years, almost altogether, being subjected to all of the usual materials that varied household uses subject them to, including plenty of good soap and water and scrubbing; and none of the vessels are in the least corroded. Aluminum spoons have been subjected to treatment with vinegar in comparison with silver spoons, and have withstood the ordeal equally as well, and are in constant use in my own home.

A careful and intelligently chosen course regarding the development of the use of aluminum in the arts, the medium of the two above referred to, determining the uses for which the metals shall be utilized in the arts from a

reasonably accurate knowledge of the properties of the metal and the requirements that will be demanded of it in its proposed applications, is the task to be accomplished in solving this portion of the "aluminum problem." Considerable has already been done in this work, and fortunately the problem is applicable to a multitudinous subdivision among the world's workers. Nothing is gained in advancement of the knowledge, welfare or skill in the arts, in the world's rapidly developing needs, except at somebody's cost.

> "Not a truth has to science or art been given,
> But brows have ached for it and souls have toiled and striven."

There is much yet to be done along these lines in solving this portion of the "aluminum problem." I believe this field to be a richer one and will yield better results to the successful investigators of the future than the one of endeavoring to find a new and more economical method of manufacture of the metal.

The late James Nasmyth epigrammatically said that "engineering is common sense applied to the use of materials;" had he added the word *intelligent*, his definition seems to me would be well nigh perfect, and that portion of my subject which referred to the "uses of aluminum from an engineering standpoint" could be stated in terms of this definition as follows: *common sense applied to the intelligent use of aluminum.*

It is along these lines that I wish to make a plea for the metal to-night, that the public interest that is now so widespread, and the work of the many inventors who are now so earnestly struggling with the "aluminum problem" be turned in this seemingly new direction of attacking the metal from an engineering standpoint—that is, exercising "common sense applied to the intelligent use of the metal."

The principal impurity of the commercially pure aluminum of to-day is silicon, which exists in two forms, one seemingly combined with the aluminum, as combined carbon exists in white pig iron, and the other in an allotropic graphitoidal modification. These two forms of silicon seem to exert somewhat different effects by their presence

in the aluminum; the combined form of the element rendering the metal much harder than the graphitoidal variety. The combined silicon ordinarily preponderates, being fifty-five per cent. to eighty per cent. of the total silicon in the metal of ninety-nine per cent. purity made by the Pittsburgh Reduction Company. The graphitoidal silicon is separated on dissolving aluminum in hydrochloric acid as a black insoluble residue, and appears like graphitoidal carbon on similarly treating gray cast iron. In fact, it has been mistaken for carbon by many superficial or ignorant observers. Carbon does not unite with aluminum except at very high temperatures, and its influence seems to be to make the metal very brittle. Metal containing carbon can readily be told by its abnormal crystalline and peculiar colored fracture.

In the electrolytically made commercially pure aluminum of to-day, the only other impurity is iron, which, if it exists in larger quantity than five or at most ten–one-hundredths of one per cent., is the result of carelessness in manufacture, or the selection of needlessly impure alumina ore or carbon anodes. The presence sometimes found of copper or lead in any quantity in the metal, is the result of needless contamination with these elements in the preparation of the ore or the carbon anodes, or in the manipulation of the pots. By allowing the pots to run for a considerable time without ore, and with a high current and very hot electrolyte as sometimes occurs in careless working of the pots, metallic sodium has been alloyed with aluminum in noticeable percentages. Upon placing such metal in hot water, the sodium will be rapidly dissolved out with considerable effervescence, and the pure metal left spongy, honey-combed and weak.

For many purposes, the purest aluminum cannot be so advantageously used as that containing three per cent., or even four per cent. of impurity, as the pure metal is very soft, and not so strong as the less pure. It is only where extreme malleability, ductility, sonorousness, or non-corrodibility is required that the purest metal should be chosen. For most purposes a small percentage of other elements

than silicon and iron are advantageously added in producing hardness, rigidity and strength. Titanium, chromium and copper can readily and cheaply be added, and are constituents that will not detract from the non-corrodibility of the metal as much as do these natural impurities that come from the ore and apparatus—additions that will give the aluminum a better color and greater strength and hardness, with proportionately less sacrifice of malleability, ductility, etc.

The properties of aluminum which will probably give it the greatest availability in the arts, are:

(1) Its relative lightness.

(2) Its non-tarnishing quality as compared with many other metals; aluminum not being acted upon by sulphur fumes at all, and being very much more slowly oxidized by moist atmospheres than most of the metals.

(3) Its extreme malleability.

(4) Its easy casting qualities.

(5) The influence of the metal in various alloys will give it advantages, some of which I will try to enumerate and call to your attention.

(6) Its high tensile strength and elasticity when weight for weight of the metal is compared with other metals, and especially when alloyed with a small percentage of titanium, silver or copper and properly worked by being rolled or hammered or otherwise drawn down.

(7) Its high specific heat and electrical and heat conductivity.

Unfortunately, aluminum is not, section for section, as has been widely claimed, comparatively a very strong metal. It is only about as strong under tensile strain, section for section, as cast iron, and has less than one-half the strength of wrought iron under ordinary conditions. Under compression, the metal, unfortunately, has a very low elastic limit, although its extreme ductility allows the metal to flow on itself so freely as to make it for special purposes a very safe metal to use in compression. I show a series of cylinders of one and one-half inch diameter, which have each had a compressive strain of 200,000 pounds applied to them,

together with the result of a compression strain of 180,000 pounds upon similar cylinders of cast iron.

The same remark applies to transverse tests on aluminum. It is not a rigid metal at all, and bends under transverse strains very readily. I append a table of results which, from our experience, I believe will show about the average tensile and compressive tests of commercially pure aluminum, unannealed:

		Pounds.
Elastic limit per square inch in tension	(castings), ...	5,000
	(sheet), ...	12,000
	(wire), . 16,000 to	30,000
	(bars), ...	10,000
Ultimate strength per sq. in. in tension	(castings), ...	15,000
	(sheet), ...	24,000
	(wire), . 30,000 to	65,000
	(bars), ...	28,000
		Per Cent.
Percentage of reduction of area in tension	(castings), ...	10
	(sheet), ...	25
	(wire), ...	40
	(bars), ...	20
		Pounds.
Elastic limit per square inch under compression in cylinders, with length twice the diameter, ...		3,500
Ultimate strength per square inch under compression in cylinders, with length twice the diameter, . . .		12,000
The modulus of elasticity of cast aluminum is about, .		11,000,000
" " " forged " " .		15,000,000
" " resilience of cast " " .		·1600
" " " forged " " .		·2200

Under torsional stress in Thurston's torsional machine, the metal has much lower modulus of rigidity than iron or steel; its maximum shearing stress in castings being about 12,000, and in forgings about 16,000, being about that of pure copper. The angle of torsion is about equal to that of the softest steel.

The following tables of tests are of results obtained since those published in the article on "The Properties of Aluminum," by Alfred E. Hunt, John W. Langley and Charles M. Hall, published in the *Transactions of the American Institute of Mining Engineers*, vol. xiii.

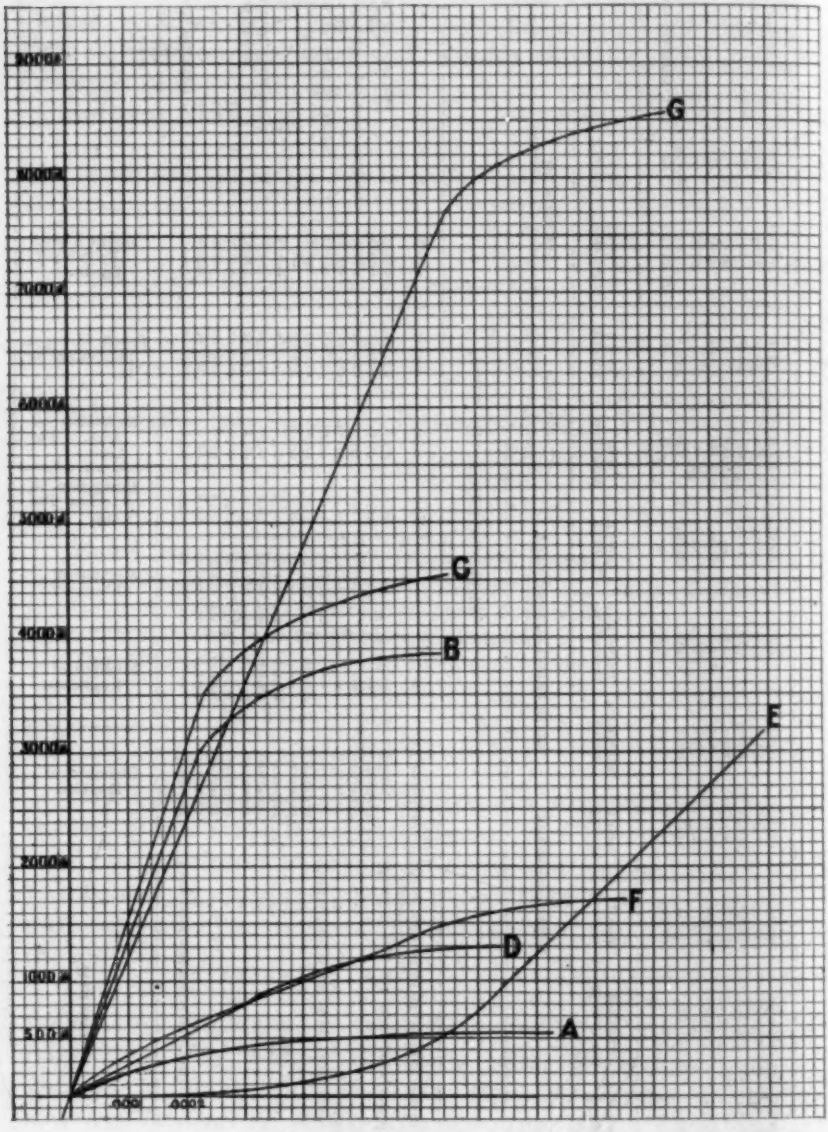
TABLE I.—TENSION TESTS.

	Elastic Limit. Pounds per Sq. In.	Tensile Strength. Pounds per Sq. In.	Reduction of Area. Per Cent.	Elongation in 8 Inches. Per Cent.	Modulus of Elasticity.	Modulus of Resilience.	Character of Fracture.	Remarks.
Cast aluminum rods ½ inch, diameter A,	—	15,334	4·70	3·9	11,000,000	—	Granular.	Very pure soft metal annealed.
" " 1¼ " B,	2,268	11,849	2·50	2·25	10,084,000	0·2127	Granular.	" " "
" " 1½ " C,	2,026	11,870	0·40	3·50	8,532,631	0·2005	Granular.	" " "
" " ⅝ " D,	5,128	12,820	10·30	1·50	15,194,074	0·0721	Granular.	" " "
" " mean of above,	3,225	13,011	4·40	2·78	11,270,268	0·1618	Granular.	" " "
Forged aluminum rods ½ inch, diameter E,	9,856	26,901	0·70	0·78	15,460,392	0·2602	Granular.	" " "
" " 1¼ " F,	6,110	17,705	3·80	2·50	9,400,764	0·1654	Granular.	" " "
" " 6-10 " G,	—	20,400	10·00	2·34	—	—	Granular.	" " "
" " mean of above,	7,983	21,270	4·80	1·15	12,430,580	0·2128	Granular.	" " "
Drawn aluminum wire, No. 16, B. & S. Gauge,	19,430	65,320	14·20	7·10	19,700,000	—	Silky.	Cold drawn metal 98 per cent. pure.
" " No. 16, "	10,500	32,310	15·30	8·50	—	—	Silky.	" " " annealed.
Aluminum casting hardened with 3 per cent. copper,	6,132	15,640	8·66	—	—	—	Granular.	
" " drop forged,	9,220	18,310	5·30	3·50	—	—	Granular.	
" sheet, No. 20, B. & S. Gauge,	6,590	23,510	9·60	2·10	—	—	Silky.	Metal of 97½ per cent. pure, remainder mostly silicon.
" " No. 10, "	9,980	29,650	4·10	1·80	—	—	Granular.	Metal cold rolled 98 per cent. pure.

TABLE III.—TORSION TESTS.

	Moment of Torsion. Inch Pounds.		Angle of Torsion. Degrees.		Extension of Outer Fibre.			Shearing Stress.			
	Elastic Limit.	Maximum Strength.	Elastic Limit.	Maximum Limit.	Elastic Limit.	Maximum Extension.	Final Extension.	Elastic Limit.	Maximum Stress.	Modulus of Rigidity.	Elastic Resilience.
Cast Aluminum 0·751 inches diameter,	—	1114·76	—	110°	—	·166	·1660	—	13,473	—	—
Forged " 0·751 "	666·49	1274·	1·56°	260°	·00003	·738	·9120	8163·	15,285	843,658	8·99
Cast " 0·980 "	—	2548·	—	72·5°	—	·0753	·0735	—	—	—	—
Forged " 0·980 "	1433·	2942·	5·0°	157·5°	·0003	·317	·4490	7802·	16,022	186,133	62·34
Cast " 0·625 "	—	478·	—	109·3°	—	·1601	·1601	—	10,133	—	—
Forged " 0·620 "	478·	755·	4·37°	57·5°	·00024	·048	·1490	10133·	16,993	434,318	18·15
Cast " 0·760 "	1036·	1115·	2·18°	36·25°	·00007	·0193	·0193	9015·	13,149	869,849	19·67
Forged " 0·760 "	319·	1194·	1·25°	168·75	·0 001	·359	·6550	3757·	14,089	461,594	3·49

TABLE II.—CURVES OF EXTENSION OF SAMPLES MARKED *A, B, C, D, E, F, G,* OF TABLE I.



It will be noted that the tensile strength of aluminum wire runs up very considerably over that of the rolled metal. This is due to the peculiar property of aluminum to harden under work. The metal requires frequent annealing in rolling; and if it is to be drawn into wire with as little annealing as possible, the tensile strength is increased very considerably. This property of the metal is increased, especially if the aluminum is alloyed with a small percentage of copper, titanium or silver.

It is perfectly feasible to produce a wire of aluminum alloyed with a small percentage of silver, titanium, or copper, which will have a tensile strength of 80,000 pounds to the square inch, and which will have, weight for weight with copper wire, an electrical conductivity of 170 to that of copper being 100. When it is taken into consideration that the copper will only have a tensile strength at maximum of (say) 30,000 pounds per square inch, against the 80,000 pounds strength of the aluminum-titanium alloy, and when the further fact that iron or soft steel wire has only a conductivity of seventeen in the same scale, and has a less, or at most only an equal tensile strength per square inch with the aluminum-titanium alloy, a wide field for usefulness for electrical conductors seems opened for the metal, even at present when the price of the wire of aluminum-titanium alloy will necessarily be considerably higher; but when such an alloy can be produced in fine wire at a price of (say) fifteen times that of the iron wire, pound for pound, then as the section can be reduced the aluminum-titanium alloy will be the cheapest as well as the most advantageous for electrical conductors.

Two things, however, should always be borne in mind in considering the applicability of aluminum for given purposes in the arts. The first is that the properties of the metal are very considerably changed as regards strength, tenacity, hardness, rigidity and color, by alloying it with small percentages of other metals, conditions that do not materially change the specific gravity of the metal. The second is the relative weight of aluminum; taking the tensile strength of aluminum in relation to its weight, it is in plates as strong

as steel at 80,000 pounds per square inch ultimate strength, and in cold drawn wire as strong as steel at 180,000 pounds ultimate.

The specific gravity of aluminum, of course, is one of its most striking properties; it varies from 2·56 to 2·70. The weight of a given bulk of aluminum being taken as one, wrought iron is 2·90 times as heavy; structural steel is 2·95 times; copper 3·60 times; ordinary high brass, 3·45 times; nickel, 3·50 times; silver, four times; lead, 4·80 times; gold, 7·70 times; and platinum 8·60 times as heavy. Most woods that would be used for structural purposes are about one-third as heavy as aluminum.

The specific gravity of aluminum is 2·56 in ingots and 2·64 in forged bars.

A cubic inch of cast aluminum weighs ·092 pound; of rolled sheet metal, ·098 pound.

	Weight in Pounds of one Cubic Foot.	*Tensile Strength per Square Inch.*	*Length of Bar in Feet able to support its own Weight.*
Cast iron, ...	444	16,000	535
Ordinary gun bronze, . .	525	36,000	9,893
Wrought-iron plates, . . .	480	50,000	15,000
Aluminum plates, ...	165	26,000	23,000
(cold rolled),	168	35,000	39,615
(cast), . . .	160	15,000	13,231
(forged), . .	165	20,000	17,700

Wherever momentum is to be overcome, as in the reciprocal parts of many forms of machinery, aluminum can be advantageously used.

For valves, for structural purposes, and for machinery where lightness is a prime factor and where the wear due to the softness of the metal in bearings can be avoided by bushing, and its pliability can be overcome by properly designed sections and by using metal hardened by alloying and by cold-rolling, drop-forging, or otherwise stiffening it up, the metal can be used advantageously and deserves further consideration.

Aluminum does not oxidize seriously so as to interfere at all with the strength of thin sections of the metal as does iron or steel; the thin film of oxide which covers the surfaces of the metal which have been long exposed to moist

atmosphere seems to prevent its being further acted upon. But it does give a surface tarnish to the metal which cannot be rubbed off with the usual metal polishing compounds without interfering with the surface of the soft metal. This, however, can be removed by rubbing with a flannel rag which has been immersed in a two per cent. solution of hydrofluoric acid and then again rubbing up the polish with a rag saturated with carbon oil. Special aluminum polishes have been devised which work very efficiently. When properly cared for, polished surfaces can thus be kept bright for a remarkably long time.

As compared with most metals, pure aluminum, under ordinary circumstances, withstands the action of wind and weather exceedingly well; and many uses to which the metal is now being successfully applied are based upon this fact. The presence of silicon in aluminum materially detracts from its power to withstand corrosion due to atmospheric influences. Metal with four per cent. or five per cent. of silicon very soon collects a thick coating of oxide upon it, if severely exposed. The fact that pure aluminum is not severely acted upon by boiling water or by steam has led to its successful use as a packing or gasket in steam connections, where lead and similar metals have been rapidly cut out, as in parts of steam and water pumps and difficult steam joints.

Aluminum is not acted upon by carbonic acid or carbonic oxide, or sulphuretted hydrogen, at any temperature less than 600° F., and these facts will undoubtedly lead to its application for many new purposes in the future.

Aluminum is found to withstand the action of organic secretions better even than silver, and for many forms of surgical instruments and apparatus such as suture wires and tracheometer tubes, the metal is already receiving very wide use. Many surgeons are having their instrument cases made of aluminum; it having the advantage that they can safely be washed clean with antiseptic solutions. It may be well, however, to say here that perspiration in handling polished aluminum does tarnish the metal, and that aluminum, like other metals, cannot retain a high polish

with frequent handling. The natural acid solvent for aluminum is hydrochloric acid. Solutions of the strong caustic alkalies, chlorine, bromine, iodine, and fluorine rapidly corrode aluminum. Ammonia gas has very little action on the metal, except to turn it a gray color. Strong aqua ammonia has a slight solvent action upon it.

I take pleasure in exhibiting two plates of about six inches square each, one of aluminum and one of copper, which have been nailed upon the wooden sides of a schooner that has made a trip from New York to the West Indies and back, and were immersed in the sea water together for four months. The sheets weighed one pound two and three-quarters ounces avoirdupois for the copper sheet, and five and three-eighths ounces for the aluminum sheet; neither sheet lost an appreciable amount by the service. The original thickness of the sheets was 0·087 inch each, and now is 0·087 inch and 0·086 inch, for the aluminum and copper, respectively, showing that the copper sheet corroded the most under equal treatment. Unfortunately for the advantageous use of aluminum as a sheathing for ships, however, the barnacles seem to thrive on the aluminum sheet, a satisfactory evidence of the relative non-corrodibility of the metal, but not of its availability for certain marine purposes.

For structural purposes under water, where metals are required, aluminum seems to be especially adapted to replace the more easily corroded cast and wrought iron and steel now in general use for such purposes. For liners and shims upon masonry foundations, aluminum is well adapted, as it flows sufficiently to allow equal bearings on all parts, and is less easily cut out then lead, and much more durable than tinned iron sheets which are now in general use under heavy structures of metal resting on metal shims on masonry.

Aluminum sheets will make a much more durable and satisfactory roofing than sheet copper now generally used in valuable buildings.

Under heat the coëfficient of linear expansion of three-

eighths inch round aluminum rods of ninety-eight and one-half per cent. purity gave results as follows:

·00002295
·00002289
·0000206
·0000230
} per degree Centigrade,

between the freezing and boiling points of water; that of iron being ·0000122, tin ·0000217, copper ·00001718.

The coëfficient being obtained in the usual way by dividing the difference in length of the test bars at two given different temperatures, by the product of the original length of the bars times the difference in temperatures.

The specific heat of aluminum, according to the experiments of Prof. J. W. Richards, is ·02143, water being taken as one.

The coëfficient of thermal conductivity of aluminum, obtained by the method of Wiederman and Franz, silver being taken as 100 and copper as 73·6, is 37·96 (unannealed aluminum); annealed aluminum, 38·87.

Aluminum stands fourth, being preceded only by silver, copper and gold, as a conductor of heat as well as electricity. One yard of annealed aluminum wire of ninety-eight and one-half per cent. purity, ·0325 inch diameter at 14° C., having ·05484 of an ohm resistance; a yard of pure copper wire having a resistance of ·0315 under like conditions. The electrical conductivity of a standard section of pure silver being taken at 100, an equal section of copper also at 100, pure gold at 78·0, an equal section of pure annealed aluminum has an electrical conductivity of about 54·20.

Pure zinc,	29·90
High brass,	21·50
Pure tin,	15·45
Soft ·10 carbon open hearth steel,	12·00
Platinum,	10·60
Lead,	8·88
Nickel,	7.89
Antimony,	3·88

Authority, Lazare Weiler. Communication to the Société Internationale des Électriciens.

This relatively high electrical conductivity when equal weights are taken will undoubtedly prove a factor of importance in developing electrical uses for aluminum.

The electrical conductivity of aluminum is increased fully five per cent. by carefully annealing even the ordinary soft wire, and with hard drawn wire the conductivity is increased by annealing nearly ten per cent.

Pure aluminum has no polarity, and indeed the commercial metal in the market is practically non-magnetic.

Pure aluminum is very sonorous, and its tone seems to be improved by alloying with a small percentage of silver or titanium. For the sounding boards of musical instruments, aluminum has been proven to be well adapted.

Pure aluminum, when properly treated, is a very malleable and ductile metal. It can readily be rolled into sheets ·0005 of an inch thick, or be beaten into leaf nearly as thin as gold leaf, or be drawn into the finest wire. Pure aluminum stands third in the order of malleability, being exceeded only by gold and silver; and in the order of ductility, seventh, being exceeded by gold, silver, platinum, iron, soft steel and copper. Both malleabi ity and ductility are greatly impaired by the presence of the two common impurities, silicon and iron.

Aluminum can be rolled or hammered cold, but the metal is most malleable at, and should be heated to, between 350° and 400° F., for rolling or breaking down from the ingot to the best advantage. Like silver and gold, aluminum has to be frequently annealed, as it hardens up remarkably upon working. Due to this phenomenon of hardening during rolling, forging, stamping, or drawing, the metal may be turned out very rigid in finished shape, so that it will answer excellently well for purposes where the annealed metal would be entirely too soft, or too weak, or lacking in rigidity to answer. Especially is this true with aluminum alloyed with a small percentage of titanium, copper or silicon. It can be safely stated, as a general rule, that under similar conditions the purer the aluminum, the softer and less rigid it is.

Aluminum can be annealed by heating and allowing to

cool gradually; the best temperature is just below the red heat. Thin sections can be annealed by heating in boiling water.

Aluminum can be easily and readily welded by the apparatus of the Thomson Electric Welding Company.

Until very lately the lack of methods for successfully soldering aluminum was among the greatest drawbacks to its introduction for many purposes. Thanks to your townsman, Mr. Jos. Richards, we have a cheap solder that works satisfactorily. I take pleasure in exhibiting soldered samples and pieces of the solder. The trouble with any solder is to get it to flow, for not only has the natural disinclination of most solders to spread over aluminum to be overcome, but also, due to its very high heat conductivity, the heat of the solder is withdrawn with such rapidity as to cause the solder to "freeze" before flowing sufficiently. This difficulty has been overcome in most cases by the use of a very hot soldering iron. In the most difficult places, the use of crystals of chloride of silver has been found to aid the flow of the solder. This use of chloride of silver for this purpose is subject to the U. S. Patent, No. 375,875, of Messrs. Page and Anderson, of Waterbury, Conn.; their patent rights being for sale by W. H. Pierce, 37 Platt Building, Waterbury, Conn.

Sound castings of aluminum can be made in dry sand moulds or in metal chills. As an evidence of this, I take pleasure in exhibiting a tea-kettle cast from the metal by the Auburn Hollow Wax Company, of Auburn, N. Y. It, however, requires some experience and expertness on the part of the founder to master the peculiarities of the metal, before perfectly sound castings can be uniformly made. The aluminum should not be heated very much beyond the melting point; otherwise it seems to absorb gases, which remain in the metal, preventing sound castings. In small quantities the metal can be best melted in plumbago crucibles; but in large quantities it can be more economically melted in a reverberatory furnace with alumina or magnesia brick sides and alumina bottom. The furnace should have a tap-hole for drawing off the liquid metal into carbon-lined

ladles. In no case need the metal be covered with a flux to assist in the fusion or to form a covering of slag. In fact, owing to the metal's lightness, the presence of any flux will tend to unsoundness, due to particles of it becoming entangled in the castings, while impurities may perhaps be added to the metal by the action of the flux on the lining of the melting vessel. The shrinkage of seventeen-sixty-fourths of an inch per foot, which aluminum has, is considerably more than that of brass, which is about three-thirty-seconds of an inch per foot.

Undoubtedly, one of the greatest uses for aluminum in the arts will be in the form of alloys with other metals. Aluminum in proportions of a small percentage added to very many different metals gives valuable properties. Among these alloys is, of course, aluminum bronze. The alloys of from two and one-half per cent. to twelve per cent. aluminum with copper have so far achieved the greatest reputation. With the use of eight per cent. to twelve per cent. aluminum in copper, we obtain one of the most dense, finest grained and strongest metals known, having remarkable ductility as compared with its tensile strength, A ten per cent. aluminum bronze can be made in forged bars with 100,000 pounds tensile strength, 60,000 pounds elastic limit, and with at least ten per cent. elongation in eight inches. An aluminum bronze can be made to fill a specification of even 130,000 pounds tensile strength and five per cent. elongation in eight inches. Such bronzes have a specific gravity of about 7·50, and are of a light yellow color. For cylinders to withstand high pressures, such bronze is probably the best metal yet known.

The five to seven per cent. aluminum bronzes have a specific gravity of 8·30 to 8 and are of a handsome yellow color, with a tensile strength of from 70,000 to 80,000 pounds per square inch, and an elastic limit of 40,000 pounds per square inch. It will probably be bronzes of this latter character that will be most used; and the fact that such bronzes can be rolled and hammered at a red heat with proper precautions will add greatly to their use. Metal of this character can be worked in almost every way that steel

can, and has for its advantages its greater strength and ductility and greater power to withstand corrosion, besides its fine color. With the price of aluminum reduced only a very little from the present rates, there is a strong probability of aluminum bronze replacing brass very largely.

A small percentage of aluminum added to Babbitt metal gives very superior results over the ordinary Babbitt metal. It has been found that the influence of the aluminum upon the ordinary tin-antimony-copper-Babbitt is to very considerably increase the durability and wearing properties of the alloy. Under compressive strain, aluminum-Babbitt shows to be a little softer than the ordinary Babbitt. A sample, one and one-half inches diameter by one and one-half inch high began to lose shape at a pressure of 12,000 pounds. A similar sample of the same Babbitt metal without the addition of the aluminum (having a composition of 7·3 per cent. antimony, 3·7 per cent. copper and eighty-nine per cent. tin) did not begin to lose its shape until a compressive strain of 16,000 pounds had been applied. Both samples have stood about an equal strain of 35,000 pounds. In comparative tests of the ordinary Babbitt metal and the aluminum-Babbitt metal, the latter has given very satisfactory results. At the works of A. W. Cadman & Co., 63 Water Street, Pittsburgh, a crank-pin bearing of a thirty horse-power engine with the ordinary Babbitt metal required resetting about every three days; and after inserting in the bearing aluminum-Babbitt strips of about a half-inch width upon the face, dove-tailed in alternately in the brass bearing, the same bearings ran under similar work for two months without requiring any attention; and when examined at the end of two months, the crank pin was found to have become very much smoother than it was before the aluminum-Babbitt had been inserted. Mr. Cadman recommends dove-tailing in the strips of Babbitt, for the reason that it gives equal bearing all over the surface. Another advantage of this Babbitt is its extreme malleability. It can be hammered out to a thin edge without cracking, whereas the ordinary Babbitt is not at all malleable. An advantage of this is that for bearings, with aluminum, the

Babbitt can be rolled into shape for inserting in the dovetailed recesses, which can be cut and drifted out at a very small expense, and the amount of Babbitt required is reduced to a minimum.

Aluminum is also being used very successfully in steel castings, and has added very considerably to the progress which has been made within the last two years in obtaining sound steel castings. A large number of steel casting companies are regularly using the metal aluminum in quantities of from one-half pound to several pounds of aluminum to the ton of steel. In the manufacture of ordinary steel ingots by the open-hearth and Bessemer processes, it has lately been shown in the article on "Aluminum in Steel Ingots," by Prof. J. W. Langley, at the January, 1891, meeting of the American Institute of Mining Engineers, that the use of aluminum in small proportions (from one-third to three-fourths of a pound of aluminum to the ton of steel) has proved to be an economical success, preventing blowholes and unsound tops of ingots.

Alloys of aluminum with copper in proportion of from two per cent. to fifteen per cent. have been advantageously used to harden aluminum in cases where a more rigid metal is required than pure aluminum. Copper is one of the most common metals used at present to harden aluminum. A small percentage of copper decreases the shrinkage of the metal and gives alloys that are especially adapted for art castings. The remainder of the range, from fifteen per cent. copper up to over eighty-five per cent., give crystalline and brittle alloys of no use in the arts; which are of a grayish-white color, up to eighty per cent. copper, where the distinctly yellow color of the copper begins to show itself.

With the exception of lead, antimony and mercury, aluminum unites readily with all metals; and many useful alloys of aluminum with other metals have been discovered within the last few years, and I prophesy that many more will be found within the next few years. I consider this field as one of the most promising for investigation of any of the "aluminum problems." The useful alloys of aluminum so far discovered are all in two groups, the one of

aluminum with not over fifteen per cent. of other metals, the other of metals containing not over fifteen per cent. of aluminum; in the one case, the other metals imparting hardness and other useful qualities to the aluminum, and in the other, the aluminum giving useful qualities to the other metals.

The alloy of a small percentage of silver with aluminum to harden, whiten and strengthen the metal, gives a metal especially adaptable for many fine instruments, tools and for electrical apparatus, where the work upon the product and its convenience are of more consequence than the increased price due to the addition of the silver. The silver lowers the melting point of aluminum and gives a metal susceptible of taking a fine polish and making fine castings.

Titanium and chromium can be readily alloyed with aluminum according to methods devised and patented by Prof. John W. Langley. This will probably prove to be the most valuable means of hardening aluminum; a small percentage of titanium rendering the metal, under work, very rigid and yet elastic at the same time. Chromium is the best metal for hardening aluminum castings; the triple alloy being best adapted where a very hard and yet elastic material is required.

More or less useful alloys have been made of aluminum with bismuth, nickel, cadmium, magnesium, manganese and tin, these alloys all being harder than pure aluminum; but it is by combinations of these metals, with additions, perhaps, of copper, lead and antimony, that alloys of most value have so far been discovered. Some are additions of only one per cent. to two per cent. of aluminum.

The modifications of pewter, britannia, white metal, delta metal, and the like, with additions of aluminum, have shown very useful qualities and will add very considerably to the demand for aluminum in the near future.

The following alloys have recently been found useful: Nickel-aluminum, composed of twenty parts nickel and eight parts aluminum, used for decorative purposes; rosine, composed of forty parts nickel, ten parts silver, thirty parts aluminum, and twenty parts tin, for jewellers' work; sun-

bronze, composed of sixty parts cobalt (or forty parts cobalt), ten parts aluminum, forty (or thirty) parts copper; metalline, composed of thirty-five parts cobalt, twenty-five parts aluminum, ten parts iron, and thirty parts copper.

Besides these, Prof. Emmens, the well-known inventor of Emmensite explosives, has great hopes for an alloy of aluminum-bronze and nickel for a gun metal.

Prof. Robert Austin has discovered a beautiful alloy, containing twenty-two per cent. aluminum and seventy-eight per cent. gold, having a rich purple color with ruby tints.

The addition of from five per cent. to fifteen per cent. aluminum to type metal composed of twenty-five per cent. antimony and seventy-five per cent. lead, makes a metal giving sharper castings and a much more durable type.

To ordinary brass, the addition of aluminum gives superior strength and better anti-corrosive qualities.

Some very marked and valuable qualities have been discovered in the use of aluminum and zinc for various purposes.

A mixture of aluminum with zinc is made by the Delaware Metal Refinery, of Philadelphia, which has proved very useful in the galvanizing bath; adding one pound of the aluminized zinc alloy to each ton of spelter contained in the bath, and one pound of the alloy additional for each 1,000 pounds of new spelter put into the bath. The effects are to make the spelter more fluid, coating smoothly twenty per cent. more surface than ordinary spelter, with a surface that is brighter, more malleable and will double-seam much better than ordinary galvanized iron. The use of aluminized zinc for this purpose is patented by Jos. Richards, of Philadelphia.

The aluminized zinc has also been added to good advantage as an addition to ordinary brass mixtures; about one per cent. to the weight of the brass mixture of aluminized zinc being used, plunged with a pair of tongs under the surface of the metal, where it is stirred with a rod. The surface of the brass mixture is then skimmed, and after waiting about half a minute, until the bubbles of disengaged gas

cease, poured as usual. The effects are to make sounder castings, increase the strength, and give a finer color to the metal, which will resist oxidation much longer than ordinary brass. Should the amount of iron in the brass mixture be high, as large an amount as two per cent. of aluminized zinc can be added to liquefy the iron. The use of aluminized zinc for brass alloys gives a heavier yield of metal than without its use; and the Delaware Metal Refinery people claim that the increased yield and sounder castings produced will much more than pay the slightly increased cost of the brass mixture by the addition of the aluminized zinc.

Aluminum has been successfully used to replace lithographic stone.

Powdered aluminum mixed with chlorate of potash is used to give a photographic flash-light, which gives much less smoke than the magnesium compounds used.

The Tacony Iron Metal Company, another well-known Philadelphia concern, has successfully produced an aluminum coating for iron, which undoubtedly will have considerable use in the future.

Samples of their work I take pleasure in showing you this evening.

To the inventors who shall produce good methods of nickel-, silver- and gold-plating aluminum so that it can take the place of german- and nickel-silver, a rich reward is in waiting.

I have endeavored in the latter portion of this lecture to indicate a few of the uses that have already been established, and the openings that seem most prominent to my own observation for the use of aluminum. Undoubtedly, there are many other fields yet waiting for the metal which will yield rich returns to the successful investigator; and I close this lecture by again reiterating the prophecy that the financially most successful solution of the aluminum problems of the future "will be in the ways of utilizing the metal in the arts, rather than in devising more economical methods of manufacture."

PHILADELPHIA AS A SEAPORT.*

By Capt. F. A. Mahan, Corps of Engineers, U.S.A.

[*Concluded from p. 202.*]

The little city of Newcastle-on-Tyne has not been backward in improving the stream which affords the means of carrying away its coals. In 1843, at some points the water was only two feet deep at low tide. The difference between low and high water was twelve and one-half feet. Even at high tide the river was so obstructed by bars, and the channel was so tortuous that vessels often needed two and three tides to reach the sea, only twelve miles away. For years the city has been at work dredging out the river, and from 1838 to December 31, 1889, the enormous quantity of 86,900,000 tons, nearly 60,000,000 cubic yards of material was removed. In addition to this great piers have been built out into the North Sea, so as to facilitate passage over the bar at the mouth of the river, and to make a harbor of refuge for vessels plying along the coast, and the Northumberland and Albert Edward docks were dug. These docks have a combined water area of seventy-nine acres. During the thirty-nine years, from January 1, 1851, to December 31, 1889, the sum of nearly $50,000,000 has been spent, and an income of nearly $28,000,000 has been received.

In the case of neither the Clyde nor the Tyne has any mention been made of the increase of prosperity of the cities of Glasgow and Newcastle. The industry most intimately associated with these cities in the American mind is their ship-building. The yards of the Clyde are celebrated, and most of the great transatlantic racers come from them. Hardly less so are the yards along the Tyne which in five years, 1880 to 1884, both included, turned out 597 ships of 1,435 tons average.

In the cases of the Clyde, the Tyne and the Manchester Canal, the work has all been done with the sanction, but

* A lecture delivered before the Franklin Institute.

without any pecuniary assistance from the general government. They are great commercial ventures which, in the case of the first two, have proved immensely profitable and the last is likely to be not less so.

Turning now to the city of Antwerp we find a new system wherein part of the work is done by the city and part by the general government. It is very difficult, if not impossible, for one not thoroughly familiar with this port to say just what has been done by each. Of one point we are sure: the general government built the magnificent quay wall on the right bank of the Scheldt, between the years 1877 and 1884, at a cost of about $8,000,000. Of another point we are sure: in twenty-five years, from 1859 to 1884, the city spent on the enlargement and equipment of its docks more than $15,000,000, or $600,000 a year. This may be called doing pretty well for a city which, in 1859, had a population of 108,500, and in 1884, 201,400. Its advantage is seen in this statement: From 1830 to 1840, the average daily tonnage entering the port was 440; from 1880 to 1885 it was 9,572, and at the present writing it is probably far beyond 10,000 tons per day.

It is useless to carry these accounts further. We everywhere find the same extensive works going on. It is only in our own country, the one of whose greatness we are constantly talking, that we find—nothing.

New York indeed has made a beginning, and so far as I am aware, it is the only one of our American cities which has undertaken the improvement of its water front in a systematic way. A plan for this work was drawn up and adopted several years ago, and since then the improvement has gone ahead, every year approaching a little nearer to completion. Whether it will ever catch up to the growth of the city is hard to say. As the method of carrying on this work is of our own country, a short account of the organization which has it in charge may be interesting.

All work along the river front is under the control of the Department of Docks, which has exclusive charge and control, subject in certain cases to the approval of the Commissioners of the Sinking Fund, of all wharf property includ-

ing wharfs, piers, bulkheads and structures thereon and waters adjacent thereto, and all ships, basins, docks, water fronts, land under water and structures thereon, and the appurtenances, easements, uses, reversions and rights belonging thereto, and which are now owned or possessed by the city of New York, or to which it is or may become entitled. It has exclusive charge and control of all operations of construction or repair, of dredging and deepening around and between piers, and of leasing and protecting all wharf property. It has exclusive government and regulation of piers, wharves, bulkheads, slips, docks, basins, etc., with all structures thereon, water thereto adjacent and land under the water. But while it has authority, with the approval of the Commissioners of the Sinking Fund, to change the location and width of piers, it has no power to change the exterior lines of piers and bulkheads as established by law.

The Department of Docks is composed of three Commissioners, who are appointed by the Mayor and who serve six years at a salary of $3,000 a year. The Commissioners must be residents of the city, and ceasing to be residents they cease to be Commissioners. They may be removed from office by the Mayor, subject to the approval of the Governor of the State. In case of a vacancy arising before the expiration of the term of one of them, the successor is appointed only for the unexpired portion of the term.

Funds for carrying on the works are obtained through the issuance by the Comptroller of "dock bonds of the city of New York." These bonds bear interest at six per cent., and are redeemable from time to time, but not before thirty years. Not more than $3,000,000 may be issued in any one year, and none of the bonds may be sold below par. The money obtained from these bonds is deposited in the city treasury, and is paid out on requisition of the Department of Docks, countersigned by the Commissioners of the Sinking Fund. It is used for payment of all work done, for salaries, for the purchase of property, or the payment of damages awarded under appraisement. Property acquired by condemnation is obtained under the same rules and regulations as that for streets and public places.

Work may be done by contract, in which case twenty-five per cent. is retained on all partial payments, or by day's labor if so ordered by the affirmative votes of all the members of the Board.

Upon the completion of the wharves, piers, etc., and their being opened for use, the department regulates all charges for wharfage and dockage, which it may alter from time to time as necessity may require. Leases may be made to special parties or corporations for terms not exceeding ten years, and agreements may be made for renewals at advanced rates for fifty years. All leases, other than those made for districts appropriated by the department to special commercial interests, are to be made at auction to the highest bidder. Lessees may be required to make all needful repairs and keep the leased property in good condition under penalty of forfeiture and damages; or they may be required to keep in order, in general terms, what is above the water while the department does the same for what is below.

The department makes all rules and regulations for the care of property and affixes penalties for their violation, not to exceed $500 fine or thirty days' imprisonment, or both, judgments to be obtained by suit in the name of the city. All rents, fines and penalties, and other money collected by the department, belong to the city and are paid into the sinking fund.

It makes an annual report, in which are given:

(1) The names, occupations and pay of all persons appointed and employed by the department.

(2) A statement of the action of the department for the past year, classified with reference to the various subjects and duties which have engaged the attention of the Board.

(3) A list of orders and rules and of the contracts made by the department, payments with the purposes and amounts thereof, and the leases drawn, together with the terms, rentals, names of lessees and description of the properties leased.

It may deepen the water near and adjoining any private wharf, pier, dock or bulkhead, or land within the city, in

such places and at such times as it may deem necessary and proper.

It may remove any vessel, raft or float from any place where it may be moored or anchored, whenever such removal may be necessary for the convenient prosecution of work doing under the department.

It must furnish mooring places for the public baths upon requisition from the Department of Public Works.

It has to assign such slips or berths in slips and at piers as may be convenient and necessary for the Department of Street Cleaning.

Such, in brief, is the organization of the New York Department of Docks. Its executive officers are a Secretary and a Chief Engineer, the latter receiving a salary of $6,000 a year.

The necessity of having the approval of the Commissioners of the Sinking Fund in certain cases is most unfortunate, and it has, at times, greatly cramped the action of the Dock Department. In fact, the Commissioners of the Sinking Fund have it in their power to put a stop to work, by refusing to countersign the requisitions for funds of the Dock Department. One Board is bad enough, but two of them is well-nigh impossible, and that the operations of the New York department have been so successful is largely, if not wholly, due to the able engineers who have directed them.

Let us examine now the relation of the Port Wardens of Philadelphia to that port, and compare their duties and powers with those possessed by the Department of Docks of New York. So far as the purposes of this lecture are concerned we may say that they have no powers at all. They can acquire no property, they can direct no work, they can take no initiative. To be sure they can play a negative part—that is to say, if a person wish to construct a wharf or bulkhead the approval of the Wardens must be had, and they must be convinced that the applicant is the real riparian owner. For the purpose of improving the facilities of the port the Wardens have no powers, and the same is true of the Harbor Commissioners.

At the present time there is no way by which anything

can be done in Philadelphia to meet the second, third and fifth conditions which should be fulfilled if this port is to take high rank.

Turning now to the fourth condition, the necessity of easy access to the interior, we find a state of affairs very difficult to overcome. In respect to inland communication Philadelphia is, without doubt, badly off. The topography of the State of Pennsylvania is such that the construction of a water connection between the eastern and western sections is well nigh an impossibility, except at a price which is prohibitory in the present apathy of the public mind toward waterways. As water will not run uphill, a canal cannot be carried over the mountains after the fashion of a railway. This makes the passage from one water-shed to another a difficult problem, and the more so if the slopes on each side of the crest be steep, which is the case in this State with those of the Susquehanna and Ohio. Still as improvements continue in canals, and lifts are constructed which raise boats carrying 300 to 400 tons through heights of fifty feet and more, we may hope to see interest in the subject revive. Who shall say that American genius cannot devise the means of raising a boat carrying 1,000 tons through a height of seventy-five or eighty feet? It will not be so daring a feat as the construction of a 550-span bridge for a railway, or that of the suspension bridge between New York and Brooklyn. These lifts are costly, to be sure, but they solve in the simplest way one great question of canals, the water supply of the summit level. They also save much time because a boat has only one lock to enter and leave for a difference of level equal to the reach of the lift, whereas with the ordinary system the operations must be repeated at each lock. The time of going up and down by a lift is very short. At Anderton, on the River Weaver, the time required to raise one boat and lower another fifty-two feet was about two minutes.

As interior communication cannot be had for the time being by water without leaving the boundaries of the State, we must turn our attention to the railway avenues of exit with which, as I have said before, the city is fairly well pro-

vided. Three important lines of railway centre here: the Pennsylvania, the Baltimore and Ohio and the Reading. The Lehigh Valley comes in and will probably make use of the Pennsylvania terminals. Of these four lines the Pennsylvania has the predominant influence and by reasons of its terminal facilities practically controls the railway freight business of the city.

The complaint is made that the Pennsylvania discriminates against the city in favor of New York and Baltimore. Why not? Is not discrimination at the very bottom of almost all business? What are card rates but a means whereby discriminations can be made in favor of one customer as against the other? To be sure discounts are largely governed by the size of the orders. Is the freight business of Philadelphia as great as that of New York? The railroad has also competition from both the adjoining cities, and makes for them rates to meet the competition. Wherein does it differ from the seller? Where the latter has a field to himself does he sell as cheap as when a competitor appears and offers better rates? A railway sells services as a manufacturer sells goods, each at the highest price to be had.

Again, the complaint is made that the railroads control legislation to too great an extent. But whose is the fault? The blame lies with us—the people. So long as we choose for office men who can be influenced by passes or other inducements offered by the railways, so long will they act in favor of these bodies unless some other body appears and offers a higher bid. If you wish unbiassed action you must choose men who cannot be biassed. If you wish independent action you must choose independent men. So long as the best men will neglect their duty to their city, their State or their country, by direct service or by direct votes, just so long will these duties be exercised by the inferior men, and the best men must suffer. Nature pardons no blunders. Whether they arise from accident, design or neglect, their consequence follows. The question of the railways is a question of business. So far as I can see they do as every one else does, but their action is further reaching, touches more people and is therefore more felt.

Some of you may ask, What bearing has this discussion of railway matters on the question of Philadelphia as a seaport? Simply this, that if a city cannot get goods from the interior to send away by sea, or cannot ship inland what comes by sea, of what use to create the port unless it be proposed to deal mainly with foreign ports? There is the whole matter. As I said before, a city is a transformer or a transhipper, or both. Under existing circumstances Philadelphia is not a great transhipper. She is a great transformer. Her true position is the same as that of Manchester, to collect materials from all parts of the world, to transform them, and then to distribute the finished product back to the world. If she cannot compete on equal terms with other places for the trade of the country, she can so compete for the trade of the world, because the ocean is free to all.

Now what should be done to make Philadelphia the port which, by her population and the capital embarked in her many enterprises, she might and ought to be? The answers are numerous and depend on the points of view and modes of thought of the writers. It may be said, however, that it is an exceedingly simple matter to evolve a plan. You may have heard the story of the way in which an Englishman, a Frenchman and a German would go to work if each were called on to contribute a chapter in natural history on the lion. The Englishman, it is said, would shoulder his rifle and start for Africa, and hunt the lion on his own ground while studying his habits. The Frenchman would stroll over to the zoölogical garden and there study the animal as he walked about or lay quiet in his cage. The German would shut himself up in his room, light his pipe, and evolve a lion out of his inner consciousness and a cloud of smoke.

Many of the persons who have ideas in matters of this sort work on the German's plan. They shut themselves up in their rooms or offices and proceed to elaborate a system which is in itself nearly perfection, but they take no account of the many failing cases which must present themselves. They lose sight of the condition of the water front, the way it is divided up among very many holders, some of it belonging to individuals living, some of it to estates;

some of it tied up with conditions in the original Penn Charter; some by conditions made by persons of recent date. Every plan proposed is met, too, by selfishness on the part of some one or other, who takes advantage of every chance to oppose what does not coincide with his pet scheme.

My own ideas on this subject, which I shall present to you, are probably as crude and open to as many objections as those of any who have presented their views.

The first step to be taken is to have it clearly understood that "man does not live by bread alone;" in other words, that a city cannot live by manufactures only. Of what use is it to convert tons of iron or wool or cords of wood into articles for the use of mankind, if these articles be kept locked up in warehouses? Who would gain by such an operation? Trade is an essential accompaniment—it might almost be called an essential element—of manufacture. The finished product must be removed and more raw material must be brought in to take the place of what has been worked up. The mind of this city has been devoted too exclusively to mere manufacturing; it has not sufficiently thought on the trading feature. Trade seeks the cheapest routes for shipments. These routes are by water, and shipments by water require a port. The manufacturers must be made to understand that a first-class port is as essential to their business as is first-class machinery. The cheaper the transportation the cheaper the raw materials here, and the finished article there. All else being equal is, of course, understood. So the first thing is to direct public sentiment to the necessity of having a fine port.

The second step is to have the means of legally overcoming the obstacles which now exist to carrying out any project. Here the Legislature of the State must step in and exercise its right of eminent domain or confer it on the city. The laws for acquiring property for public use are sufficiently strong to make this a simple matter. It will take time and doubtless much litigation, but the principles are simple. Even when they must be beaten in the long run, the selfishness and cupidity of people will lead them to oppose

all improvements in every possible way and by every possible crook. Naturally there must be some body appointed to represent the State or the city as the case may be, and this body will be doubtless somewhat on the same plan as the Department of Docks of New York, but it should not be subject to the whims of some other body, which knows nothing of its matters and which may merely wish to exercise a little arbitrary authority to show its power, without regard to the injury done to the work. But the organization of such a body cannot be made in a day, and will require much care and thought in elaborating its composition and its duties.

After the body to carry on the work has been appointed, its first duty will be to prepare a plan for the improvement. This plan will probably consist of a bulkhead wall running along the side of the river, and piers built out perpendicular thereto. Circulating space must be had from pier to pier and from the piers to the city, so that teams and cars may move freely, and this involves the widening of Delaware Avenue.

In all the articles and interviews which I have read in the daily papers, on the subject of making Philadelphia a greater port than it is now, there is one idea constantly advanced which seems to me vicious to the last degree. Every one admits that there should be a broad street along the bulkhead so that there may be room for drays and teams, and also for railway circulation. One element of successful work is space. Where space is lacking a jam is going to exist from time to time. A jam means loss of time and temper. Loss of time is translated by loss of money, and loss of temper by useless wear of the physical and nervous systems. A broad street is absolutely necessary.

The one way mentioned for widening the street is that of placing the bulkhead line further out in the river. This idea, to my mind, is bad. Water is the life of a seaport, and without water it cannot exist. Space is needed for free circulation in the river as well as on shore, but space has never in this world been had by contraction or subtraction. Furthermore we must bear in mind that the tendency of

ships is to greater size, and greater size will require more room for handling. This shows us that the experiment of trenching on the waterway may be dangerous and full of disadvantages. The widening of the street can be far better made on the side opposite the river. It would be to my mind a better solution to remove everything from the river to the west side of Front Street I know full well that this is going to raise a storm of opposition, and at once the cry of the great cost of such a proceedure will be heard.

Between 1881 and 1884, the city of Antwerp, in Belgium, having at that time a population of 195,000, did not hesitate to expropriate 630 different buildings. During a visit to that city in the spring of 1884, I saw some of the houses which were to be removed, and they were far better than anything which I have seen along the river front of Philadelphia, the sugar refineries excepted, and I was informed by the assistant engineer that they were fairly representative of what had gone before.

The difference between the foreign and American methods is well seen in this. Here cheapness in first cost generally rules in the beginning, with endless inconvenience later on; there the question is studied carefully, the best course is adopted and the work is carried forward consistently on that line. There is no reason why we should not adopt a foreign idea if it be a good one. All the wisdom of the world is not sheltered by the wings of the American Eagle. Other nations have done and are still doing work which we may study with profit.

Have a care that no mistake be made. The city can spread out into the country, it does not need the river, but your commerce needs all of the river which is to be had. Preserve the river and, if it be necessary to do so, tear down twice or three times 630 houses. The city can well afford the first cost, and the result you may be sure will justify the deed. Again, all this need not be paid for at once. As the buildings are taken one at a time, their appraised value can be paid, and coming a little at a time, the cost will not be felt.

And here let me call your attention to a future danger.

I learn that the Pennsylvania Railroad is already trying to mortgage the future, and obtain possession of Delaware Avenue so soon as it can and lay its tracks to the exclusion of all comers, the city included. Tracks on Delaware Avenue are an essential feature of any improvement, but they should belong to the city and be controlled and administered by the city, or by the body in which the care and management of the wharf system are invested by the Legislature. This service must be absolutely impartial.

In referring thus to the Pennsylvania, I am moved by no idea of hostility to that road. I merely wish to state emphatically that the management of the pier service should be absolutely impartial and should be kept out of the hands of any railroad company whatever.

The question of money will have to be carefully considered. But here comes in that which is to me a curious feature of the American character. In talking with some persons on this subject, the great cost of such an undertaking as the improvement of the front, the removal of buildings, equipment of quays and piers with proper machinery, has been mentioned as militating against it. It would undoubtedly be a tremendous thing to think of spending $20,000,000, for example, in a month or a year, and in considering the subject, they seem only to see the expenditure of that amount in one block to be made to-morrow or next day. The principle on which the work is done is the same as that on which a man buys his house from a building society. If you call on a man having a yearly wage of $1,200 to pay $2,000 cash down for a house, you scare him off, but if you give him a long period in which to make his payments, a little every month, in time he has his house without incurring any hardship. So, for the city to pay out (say) $20,000,000 in one year would be tremendous, but spread this over ten years and it reduces to $2,000,000 a year, or over twenty years, and it comes down to only $1,000,000. Then, too, the income from such works is apparently great. Witness the Clyde and Tyne improvements, where the income has been from fifty to sixty per cent. on the outlay. The method of raising the funds I

shall not discuss, as that is properly the work of trained financiers.

After the plan of the work has been adopted and the means of raising the necessary funds provided, the execution must be begun and carried forward along the approved plan. To be sure there will come up slight changes in details from time to time, but there must be no radical departure from what has been approved.

Changes of this sort are provided for in the New York laws, but I think that the approval of the Commissioners of the Sinking Fund is bad. If approval must be had it would better be from an advisory commission of citizens interested in the commerce of the port and in the navigation of the river, as they would appreciate the wisdom of a change of detail far better than could a commission composed probably of politicians.

In the execution of this or any similar piece of public work, it is absolutely necessary that the charge of it be given to a man of education and broad experience. The Archduke Charles of Austria, one of the great writers on the art of war, says: "A man can become a great captain only by passionate and unremitting study and long experience. What one man has seen by himself, does not suffice, for what life of man is fruitful enough in events to give universal experience? And who is the man that can have the opportunity of *first* practising the difficult art of the General *before* holding that important office? It is by adding to one's own stores of knowledge the information of others, by weighing the conclusions of one's predecessors and by taking, as a term of comparison, the military exploits and the events great with results which the history of war gives us, that one can become skilful in war." By changing very few words what is here said applies with equal force to the engineer. He must have knowledge, he must have experience. What others have done he must have made his own.

One great trouble of our American people has been, until within very few years, the desire for the so-called practical man; in other words, for the man whose knowledge is bounded by the extent of his own work. Educated in many

cases by men as ignorant as himself, he thinks that the sum of human wisdom in his particular line is in his own possession. Wherein the deeds of others differ from his modes, therein are they wrong. By such men, alas! is almost every profession in this country overrun, and this is true of engineering in probably a greater degree than any other. Men who do not even know how to set up a transit or a level properly, call themselves engineers and hold themselves ready to deliver an opinion, at five minutes' notice, on subjects to which great minds have given years of toil. From this condition we are gradually emerging. The many excellent special schools throughout the country, the various engineering reviews and periodicals, show that the demand for educated men is on the increase and that the people begin to appreciate that only good tools do good work.

After the engineer has completed his studies and prepared his plans for the execution of the work, it may be well as an act of prudence to submit them to a commission of experts, in order to have the assurance that nothing has been overlooked. As a rule, I do not believe in commissions. It stands to reason that no body of men can gain, in a few hours or days, the knowledge which has been acquired by the one man who has devoted months and even years to his special work. A commission generally ends in one of two ways: (1) The individual work and force of one member may dominate the whole body, in which case the report is that of one man; or (2) if all be men of a certain degree of force, or one or two of them of a certain degree of obstinacy, the report is a compromise and is of small value. No two men ever looked at the same picture with exactly the same light at the same time. One point seems essential to one man; another to the second, and so on.

Of one thing those who have the work in charge may be sure. No matter what plan may be adopted there will be plenty of condemnation and plenty of suggestions. The condemnation will come mainly from selfishness, and the suggestions from ignorance. It is impossible to satisfy every one. Our friends of the press frequently do much unintentional damage to matters of this sort by publish

ing as valuable the opinions of persons who have not the knowledge necessary to give an intelligent opinion. For example, suppose the case of a reporter asking a lawyer or a merchant his opinion, of some special engineering feature of the plan which may be adopted for the improvement of the harbor facilities. What would their opinion be worth? Just about as much as that of an engineer on some technical point of bank management. The lawyer and the merchant, assuming them to be intelligent men, are of the class to consider the business bearings of such a scheme. They throw valuable light while the question of to do or not to do is under discussion, but that stage once reached their function ceases and the matter passes into the hands of the engineer, because the doing of the work involves technical questions which the technical expert alone understands. Just as when it is a question of a suit in court; the laity may say whether or not the suit be advisable, but once in court it must be left in the hands of the lawyer, the expert.

Another class of men from whom trouble is to be expected is a certain sort of scientific men who are students only, men who have had charge of no work, who have the theory of their profession at hand, but who, for lack of practical experience or disposition, cannot adapt themselves to circumstances. Principles in any science are few; in their application is difficulty. The student generally knows what is best, but he lacks resource in makeshifts when the best is not at hand. Men of this sort are invaluable in their way, which is to take work done and dissect it, point out wherein lies departure from principles and where principles have not been well applied. But the acceptance of their suggestions must be greatly governed by circumstances. Every science owes a large debt to the many earnest men of this stamp for whom one can have no other feeling than that of respect, even if he cannot always uphold their judgment.

The method of organizing and doing a work of so great magnitude as the improvement of the water front of Philadelphia is one which needs careful thought. One obstacle,

in fact it would be better to say two obstacles, stand in the way of carrying on public improvements successfully and economically. The first is that most false idea that every piece of public work, whether of the general government, of the State or of the city, must be run to the advantage of the party in power. If the administration be Democratic the work is to be used for Democratic needs, or if Republican no Democrats need apply. Look at every sort of government in the country, and what do you see? Every office is for the reward of party service so far as the party in power for the time being can carry out the idea. But pray what has protection or free trade, or the passage or non-passage of a Federal election bill to do with laying out a proper line for a bulkhead, or for putting a stone truly and solidly in a wall? For the first are needed men of ability to grasp the situation, and for the second men of experience in spreading a bed of mortar and setting the stone thereon. Now will any one say, and so saying, does he really believe that because a Republican administration happens to be in office in Washington, a proper selection of the bulkhead line or the true setting of a stone can only be had by means of a high protective tariff, or that because the administration is Democratic the same operations can only be performed under the influence of a reduction in the tariff? Naturally, the idea is absurd.

The second obstacle is that men of influence in the community, of broad views, of successful administration of large business affairs, will not take part in a work of this sort.

Why this is so I do not understand. In times of war or of other great public commotion these same men stand ready to drop everything to go forth to battle, and even to die for the cause which they have at heart. In times of peace no inducement is sufficient to make them act for the public good, if it involve any sacrifice of time or money, unless indeed the loss be made up by some other consideration.

So long as great matters like building quays and piers are to be left to politicians, the people do not care to have their money spent for so-called public improvements. They

feel that what is done represents but a small part of the total outlay.

The American is patient and long suffering; he is also very intelligent and wide-awake. After beginning a piece of work which he is determined to finish, he may allow double or even treble prices to be paid once, but when he finds how money has been squandered on one piece of work, he does not care to give an opportunity of the same sort again. If it were suggested that a great improvement like that of the water front of Philadelphia should be undertaken by the city government, I should not be surprised to see the whole population in arms against the proposal. Why? Seek the answer in the City Hall.

Whoever may be the men charged with carrying out this great work, they may be sure that if they seek honestly to do their duty as it should be done, their place will be no sinecure. They will be roundly abused by every man who has an axe to grind; they will be accused of every thought except the one of single-minded acting in the interest of the people; charges will be made against the honesty of their administration; "cranks" of every kind will haunt them, and selfishness and greed will pursue them in all sorts of shapes at every turn. Their days will be a burden, and their nights will be without rest. But through it all will shine a bright guiding star, the thought that the result of their labors will abundantly justify their struggles. Rome was not built in a day, and no great work ever came from a small idea. To make the port what it should be is the work of years, and to be worthy of the city it must be conceived on a grand scale.

A COMPUTATION OF JOULE'S EQUIVALENT.

By R. H. Thurston.

Some years ago, the late Dr. Pliny E. Chase, then of Haverford College, published in the *Journal of the Franklin Institute* a series of articles of singular interest, and of curious result, often in which he traced what he called certain harmonies of nature, exhibiting some strangely related or oddly coincident physical laws and constants, and in which he deduced a number of remarkable conclusions. He subsequently published a short paper, reprinted in the *Philosophical Magazine*, in which he showed some reason for anticipating that it might ultimately prove that the value of γ, the ratio of specific heats of gases, is simply the numerical quantity

$$1 + \frac{4}{\pi_2} = 1{\cdot}405285$$

(*Phil. Mag.*, 1885, p. 520.)

It occurred to the writer to compute the value of J, the mechanical equivalent of heat, from this assumed value of γ. Taking the best values of constants determined by Regnault, referring all quantities to the air thermometer, and taking air as the gas to which the constants so selected should appertain.

From the well-known equations deduced by both Rankine and Clausius, we have the equality,

$$C_p - C_v = R = \frac{p_0 v_0}{T_0}$$

or the difference between the two specific heats is constant, a fact first pointed out by Carnot, and later proved by the modern methods of thermodynamics by the founders of that science.

Since we take

$$\frac{C_p}{C_v} = \gamma$$

we have

$$C_p = J\,c_p = \frac{\gamma}{\gamma - 1}\,R;\; J = \frac{\gamma}{\gamma - 1}\cdot\frac{R}{C_p}$$

and taking as Regnault's most probable values of C and of R, in British measure, 53·37 and 0·2375, we have

$$J = \frac{1{\cdot}405285}{{\cdot}405285}\cdot\frac{53{\cdot}37}{0{\cdot}2375} = 778{\cdot}12$$

in foot-pounds, or 427 kilogrammetres per calorie. This corresponds to about 775 on the mercurial thermometer, falls within about one-eighth of one per cent. of the value assigned to J, by the British Association Committee of 1876, and is somewhat lower than the figures obtained at the temperature of maximum density of water by Rowland in 1880. This determination would seem to lend some color of probability to the conjecture—for it seems to have been little more—of Dr. Chase. In further, and perhaps more satisfactory, confirmation of this, as at least a closely approximate value, as have the work of Dr. Röntgen, who, in 1872, obtained $\gamma = 1{\cdot}4053$, as a mean of ten best observations. (*Pogg. Ann.*, 1873, s. 580.) The probably most uncertain datum involved in this computation is the value of R; but it is probable that all these figures are very accurate and the computed value of J must be correspondingly so. Further examination of the value of R, which involves the location of the absolute zero, is desirable, however.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, March 15, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 15, 1892.

Dr. W. H. WAHL, President, in the chair.

Dr Wahl called attention to a number of bills for subscriptions to journals, the contraction of which had already been authorized. On motion, the Treasurer was instructed to pay them.

Dr. S. C. Hooker read a very interesting paper on derivatives of lapachic acid. Dr. Hooker included in his paper a *résumé* of some of the more important results obtained by him during the past two years and also contrasted the views entertained by E. Paterno and himself. The paper was received with marked attention and interest by the members present. Specimens of the substances discussed were exhibited. The complete publication of these results will be deferred by the author for some time.

The section then adjourned. WM. C. DAY, *Secretary*.

NOTES ON IRON IN BONE-BLACK.

BY DR. BRUNO TERNE.

The freshly-prepared bone-black of the market yields on an average from 0·1 to 0·3 per cent. of iron in the form of metallic iron, originating principally from iron mixed with the bones gathered up by the junk dealers, another portion coming from the wear and tear of the bone crushers and mills, and a very little from the iron vessels used in burning the bones.

Having been in charge for the last fifteen years of one of the largest plants for manufacturing bone-black, I had never experienced any trouble with our product, on account of the iron, until several months ago, when one of our patrons complained of an excess of iron in our black, which, according to his investigation, had run up in one instance to one-half of one per cent.

This complaint was coupled with the assertion that an increase of 0·25 per cent. of iron above the average would materially impair the process of refining sugar.

This charge coming from a source commanding serious consideration, caused us to look into this matter thoroughly, but an examination of the literature of sugar refining, covering a period commencing with 1872 (*Wagner's Jahresberichte*) up to date, failed to disclose a single case in corroboration of the above-cited assertion.

The more I thought over the matter the more I became convinced that the complaint made against our black, that it impaired the work of refining sugar liquors, was merely a convenient pretext to shield some irregularities in the process of refining, which otherwise would have to be shouldered at home. We all know that organic acids will dissolve iron, but in refining sugars the liquors should be free from acids or at least nearly made free by previous neutralization; the traces of free organic acids must certainly all be absorbed by the six to seven per cent. of carbonate of lime contained in fresh bone-black. The fact that in discarded black the yield of carbonate of lime is reduced to three or four per cent., and the yield of iron considerably raised, demonstrates clearly that fresh black operates to free sugar liquors from iron as well as other impurities.

In order to ascertain what effect a solution acidified with organic acid would have on the iron in bone-black, I prepared two solutions of citric acid containing respectively 0·1 per cent. and 0·25 per cent. of free acid.

The acidity of these solutions is so great that no sugar liquor entering filters will ever approach it in acidity.

I selected a black which had given by analysis a yield of 0·5 per cent. of iron, and made the following experiments:

	Per Cent.
(*a*) 5 grammes of black with 500 cc. citric acid solution of . .	0·1
(*b*) 10 " " " " " . .	0·1
(*c*) 5 " " " " " . .	0·25
(*d*) 10 " " " " " . .	0·25

I exposed the four flasks on the top of a steam heater for twenty-four hours to a temperature of 150° to 160° F., after

which I tested the still acid solution for iron with potassium sulphocyanide and potassium ferridcyanide, but no trace of iron could be found in the solution.

Not satisfied with this I kept the flask for eighteen hours on a steam-bath at a temperature of 200° to 212° F.; the results of the two experiments were absolutely the same.

To operate on a sample of black large enough to place the result of the experiment beyond any doubt, I took 250 grammes of the same black yielding one-half per cent. of iron and treated the same with two litres of citric acid solution containing 0·25 per cent. free citric acid, for twenty-four hours on the steam-bath at nearly 212° F.

At the end of this time the acidity of the solution had completely disappeared and the absolutely neutral solution showed not a trace of iron with the most sensitive reagents (potassium sulphocyanide and potassium ferridcyanide).

I went still a step further and prepared a solution of iron in citric acid, 200 cc. of which contained 1·01 grammes of iron. I took 100 cc. and diluted to 500 cc.; I mixed the dark-yellow solution in a flask with 500 grammes of fresh regular sugar-house black, boiled up for thirty minutes, filtered and obtained a perfectly limpid solution which contained not a trace of iron.

This experiment proved to my own satisfaction that an accidental excess of 0·25 per cent. of iron in fresh black could not be charged with creating irregularities in the process of refining sugar liquors. But not being an expert in sugar refining I submitted this problem with the above results of my own researches to my friend, Dr. Arno Behr, now Secretary and Treasurer of the Chicago Sugar Refining Company, an acknowledged expert in this branch of chemical industry at home and abroad. I submit herewith an abstract of his letter:

CHICAGO, January 4, 1892.

MY DEAR DR. TERNE: * * * "Iron is a very objectionable substance to have in filtered sugar solutions, because the refined soft sugars which are produced from such solutions take on a more or less gray appearance, which reduces

their value considerably compared with others, which are free from iron and of a bright yellow color.

"Colonial raw sugars contain sometimes a considerable amount of iron, and in the absence of good chemical methods for the removal of this iron from the unfiltered liquor, the refiner relies on the bone-black to absorb it.

"In some refineries the sugar solutions enter the black practically neutral, in others they are left a little acid, but this is of no consequence, for you have found yourself that new black will absorb the iron even from a strongly acid solution. Even old working bone-black contains enough carbonate of lime (three to four per cent.) to neutralize any considerable excess of acid. There is, however, a considerable difference in the behavior of new and old black. Say you want to filter 100 pounds of dry sugar over 100 pounds of bone-black. Say this sugar contains two to three-hundredths of one per cent. of Fe_2O_3. The solution will come from the new black absolutely free from iron, while from the old black half of it perhaps will be free, and the other half will contain it in increasing quantities.

"This will happen with properly neutralized liquor and without any fermentation having occurred. Even if the sugar solution enters the black free from iron, towards the end it will come from the old black containing iron.

"It works this way without any attempt having been made to wash the liquor out of the black. As soon as that is done matters become worse. Even from very good black the diluted sugar solution carries away a certain amount of iron.

"Now in working it is found that the amount of iron increases in the black with its age, and that in the same proportion the amount of iron increases in the liquor. There is no way of removing the iron once absorbed by the black.

"There are three sources of iron in the black:

(1) "The iron originally contained in the black.

(2) "The iron in the raw sugar.

(3) "The iron taken up by the liquors and the bone-black in the sugar refining.

"The liquor has very little chance to dissolve iron, but

the bone-black gets more or less of it by its passages through the kilns. The iron in the raw sugar the refiner has to take and make the best of, but in the case of the iron in the new black he will naturally fall back on the bone-black manufacturer and I do not blame him.

"It is reasonable to expect that a black with 0·1 per cent. Fe will furnish iron-free liquors for a longer time than one with 0·3 per cent. Fe. Most of the iron in new bone-black is in the metallic state and can be removed by running the crushed black over a magnetic separator.

"With best regards, Yours very truly,

"ARNO BEHR."

Certainly every one will agree with my friend, Dr. Behr, that 0·1 per cent. impurity of anything is to be preferred to 0·3 per cent.; the self-interest of the manufacturer will command the adoption of such means as to keep the percentage of iron as low as possible.

In the interest of manufacturers of bone-black everywhere, I thought it, however, of sufficient importance to refute the theory that an accidental excess of a fraction of a per cent. over the acknowledged unavoidable proportion of iron in new black, could be held accountable for any disturbance in the process of sugar refining, and to have my protest recorded with the section against such a claim.

This point has been fairly covered by my own experiments, and is clearly corroborated by the opinion of one of the most competent sugar chemists of this country.

Regarding the chemical methods of iron determination which are far too laborious to perform every day, I have been trying to find a method which could be carried on with sufficient accuracy without requiring previous chemical training.

I found that a boy, with the help of a magnet, could, by exercising the necessary care, make a determination, sufficiently accurate for the daily control of a bone-black mill.

Take 100 grammes of the black and spread it in a thin layer over a sheet of white paper, then plow through it with a good magnet (I am using a six-inch horseshoe) and it will be

found that most of the iron will be picked up at the first few passes.

After repeating the passes of the magnet in every direction, carefully observing that no part of the mass is missed, in a very few minutes all the iron will have been gathered on the watch glass ready for weighing. The results thus obtained come sufficiently close to those obtained by chemical test to serve as a control upon the process of manufacture, as the following examples will show:

The following tests have all been made within the last four months:

	By Chemical Analysis. Per Cent. Iron.	*By Magnetic Test. Per Cent. Iron.*
October, 1891, ...	0·360	0·410
1891, ...	0·160	0·219
December, 1891, ...	0·387	0·501
January, 1892, ...	0·100	0·130
1892, ...	0·169	0·213
1892, ...	0·080	0·107
1892, ...	0·199	0·224

While the magnetic test is invariably too high, it is sufficiently close to control the work of the black mills. The adherence of particles of carbon to the iron fully explains this result.

Regarding the chemical determination of iron, I consider a previous incineration of the black necessary, because there is a possibility that traces of organic matter left in the fresh black may be mistaken for iron by the reduction of the potassium permanganate.

On the use of Oil in Ammonia Gas Compressors and its Influence on the Efficiency of the Compressors.*

By Dr. Hans von Strombeck.

At the suggestion of Mr. Louis Block, Chief Engineer of the De La Vergne Refrigerating Machine Company, of New York, I conducted a series of experiments in the year 1887 for the purpose of determining the influence, which the injection of the oil into the compressor of this company's machine has on the efficiency of the gas pump. There had been considerable controversy on this point, and it was with the view of settling finally this question of dispute that a sufficient number of carefully conducted tests under varying conditions of pressure and temperature were made. The results of my investigations are laid down in the following treatise, accompanied by a number of tables and curves, which will fully illustrate the matter.

In the old form of the De La Vergne single-acting compressor, the cold oil was drawn by a plunger-pump from a reservoir or tank (the low-pressure or vacuum tank), which communicated by means of a pipe with the suction side of the machine, thus maintaining in the tank a constant pressure equal to that under which the liquid ammonia evaporated in the cooling-coils of the system. The oil-pump on its down-stroke discharged the oil thus drawn from the low-pressure tank into the gas-compressor, while the piston of the latter was likewise on its down-stroke, *i. e.*, after the compressor had taken its full complement of gas. On the up-stroke of the compressor-piston the gas and oil were discharged through the large valve of the dome, the oil following the gas after the latter had passed out of the compressor, both being heated in consequence of the compression of the gas. Under the increased pressure of compression a certain amount of ammonia gas was absorbed by

* From the Laboratory of the De La Vergne Refrigerating Machine Co.

the oil present over the piston. The oil thus charged with gas and after leaving the dome of the compressor was dropped into a separator, the so-called pressure tank, where it collected at the bottom. From here it passed through an oil-cooling coil and was collected at the bottom of the before-mentioned low-pressure oil tank, and being there exposed again to the suction-pressure of the machine, lost the identical amount of gas which it had previously absorbed during the compression period in the compressor. This amount of gas passed off into the suction-pipe of the gas-pump without doing any efficient cooling work, and therefore represented a certain loss in the efficiency of the compressor, which to ascertain was the object of my experiments.

To solve the question it was necessary to first make a series of tests as to the amount of ammonia, which the oil (or liquid base as it has been termed by the De La Vergne Company) could hold in solution under different pressures and temperatures. Though it is generally believed that the quantity of gas absorbed by a liquid (the temperature remaining the same) is proportional to the absolute prevailing pressure, it will be seen at a later place of this paper, that this law does not hold good as strictly as is generally believed. Therefore, it is always necessary to ascertain by tests, whether or not a gas follows this law. Thus the amount of ammonia which the liquid base could hold in solution under different pressures and temperatures being known, and the pressure and temperature of the oil in the low-pressure oil tank as well as in the high-pressure oil tank being likewise known, the amount of ammonia contained in one charge of oil can be found by calculation, first when this oil is injected into the compressor, and second when it leaves the compressor. The difference between the two quantities of ammonia represents the loss during each stroke of the compressor, and the number of cubic inches occupied by this ammonia under suction-pressure, and the cubical contents of the compressor being known, the ratio of the two volumes will represent the percentage of loss.

To illustrate this by an example, let us assume a single-acting compressor of 12 inches diameter and 24 inches

stroke, the contents of which are equal to 2,714 cubic inches. It is the practice of the De La Vergne Company to inject into this compressor thirty-five cubic inches of liquid base, at each down-stroke.

Now let us assume:

A condensing pressure of 146·7 pounds absolute, temperature 150° F.
A back pressure of 44 " " " 70° F.

According to Table V:

	Volumes.
1 volume of liquid base absorbs at 146·7 lbs. absolute pressure and 150°,	12·430
1 " " " 44 " " " " 70°,	6·599

both volumes reduced to normal pressure (14·67 pounds) and 32° F.

One volume of oil therefore loses, if reduced from 146·7 pounds and 150° to forty-four pounds and 70°: 12·430 — 6·599 = 5·831 volumes of ammonia at normal pressure and 32°; and if subjected to a pressure of forty-four pounds and a temperature of 70° these 5·831 volumes will occupy only 2·09 volumes. Consequently the ammonia which is allowed to escape out of the thirty-five cubic inches of oil injected, occupies 73·15 cubic inches under pressure and temperature of the suction-side of the compressor; and the contents of the latter being 2,714 cubic inches, 2·69 per cent. is the loss in efficiency of this compressor.

In the new system of oil-circulation in the De La Vergne compressor even this small item of loss is entirely obviated, because the oil is now injected under pressure into the compressor after the same has taken in its full supply of gas.

The oil or liquid base used in the De La Vergne machine is a mineral oil, because all vegetable and animal oils saponify in connection with ammonia.

In distilling this oil in fractions the result is as follows:

	Per Cent.
Volatile bodies, distilling over at 464° to 500° F.	0·5
500° to 536° F.	0·7
536° to 572° F.	0·4
above 572° F.	92·2
Non-volatile residue, ...	6·2
	100·0

The flashing point is at 380°, the congealing point at 6°, the specific heat is 0·4618.

TABLE I.—SHOWING THE SPECIFIC GRAVITIES OF LIQUID BASE AT TEMPERATURES FROM 50° TO 280° F.

Temperature.	Spec. Grav.	Temperature.	Spec. Grav.	Temperature.	Spec. Grav.
50	0·9115	130	0·8847	210	0·8375
60	0·9069	140	0·8812	220	0·8538
70	0·9057	150	0·8778	230	0·8501
80	0·9037	160	0·8744	240	0·8464
90	0·8991	170	0·8711	250	0·8427
100	0·8952	180	0·8674	260	0·8390
110	0·8913	190	0·8648	270	0·8353
120	0·8881	200	0·8612	280	0·8316

While perusing the literature on ammonia, I found some data which I think are not as generally known as they ought to be and which I, therefore, give in the following. Determination of the quantities of ammonia, which are absorbed by water at atmospheric pressure, have been made by Sims, Bunsen, Roscoe and Schorlemer (cf. *Ann. d. Chem. and Pharm.* 117, 118). I give the figures obtained by them in Table II, a graphic representation in *Fig. 2*. It will be seen that the figures obtained by these scientists differ more or less from one another, and the rather surprising fact will appear that even at 212° ninety-seven volumes of ammonia gas are still absorbed by water.

Determinations of the quantities of ammonia which are absorbed by water at different pressures, have been made by Sims (*ibid.*). I give the figures obtained by him in Table III. In *Fig. 3*, I give a graphic representation, the full lines showing how the absorption of ammonia by water in reality takes place according to Sims' tests; the dotted lines showing how the absorption ought to take place according to the above-mentioned law, if we take the figures of Sims, Bunsen, Roscoe and Schorlemer, respectively, as the true figures of the quantities of ammonia absorbed by water at 32°, 68°, 104° and 212°, respectively, and atmospheric pressure. It will be seen that the two lines only coincide at 212°, at the

lower temperatures the amount of ammonia absorbed being more or less smaller than it ought to be.

TABLE II.—SHOWING THE ABSORPTION OF AMMONIA BY WATER AT DIFFERENT TEMPERATURES AND ATMOSPHERIC PRESSURE, ACCORDING TO DIFFERENT AUTHORS.

One Volume of Water absorbs the Following Quantities of Ammonia:

	Sims.		Bunsen.		Roscoe & Dittmar.			Sims.		Bunsen.		Roscoe & Dittmar.	
° F.	Grammes.	Volumes.	Grammes.	Volumes.	Grammes.	Volumes.	° F.	Grammes.	Volumes.	Grammes.	Volumes.	Grammes.	Volumes.
32·0	0·899	1,180	0·799	1,050	0·875	1,150	125·6	0·274	359	—	—	0·214	281
35·6	0·853	1,120	0·756	993	0·833	1,094	129·2	0·265	348	—	—	0·200	262
39·2	0·809	1,062	0·717	942	0·792	1,040	132·8	0·256	336	—	—	0·185	239
42·8	0·765	1,005	0·681	895	0·751	986	136·4	0·247	324				
46·4	0·724	951	0·649	852	0·713	936	140·0	0·238	312				
50·0	0·684	898	0·618	813	0·679	892	143·6	0·229	301				
53·6	0·646	848	0·592	777	0·645	847	147·2	0·220	289				
57·2	0·611	802	0·566	743	0·612	803	150·8	0·211	277				
60·8	0·578	759	0·542	712	0·582	764	154·4	0·202	265				
64·4	0·546	717	0·519	682	0·554	728	158·0	0·194	254				
68·0	0·518	683	0·498	654	0·526	691	161·6	0·186	244				
71·6	0·490	643	—	—	0·499	655	165·2	0·178	234				
75·2	0·467	613	—	—	0·474	622	168·8	0·170	223				
78·8	0·446	585	—	—	0·449	589	172·4	0·162	212				
82·4	0·426	559	—	—	0·426	559	176·0	0·154	202				
86·0	0·408	536	—	—	0·403	529	179·6	0·146	192				
89·2	0·393	516	—	—	0·382	502	183·2	0·138	181				
93·2	0·378	496	—	—	0·362	475	186·8	0·130	170				
96·8	0·363	478	—	—	0·343	450	190·4	0·122	160				
100·4	0·350	459	—	—	0·324	425	194·0	0·114	149				
104·0	0·338	444	—	—	0·307	403	197·6	0·106	139				
107·6	0·326	428	—	—	0·290	381	201·2	0·098	128				
111·2	0·315	414	—	—	0·275	361	204·8	0·090	118				
114·8	0·304	399	—	—	0·259	340	208·4	0·082	107				
118·4	0·294	386	—	—	0·244	321	212·0	0·074	97				
122·0	0·284	373	—	—	0·229	301							

In Table IV, I give the figures showing the quantities of ammonia absorbed by liquid base at temperatures from

32° to 300° and atmospheric pressure; *Fig. 4* shows the graphic representation of the same. In Table V, I give the figures, and in *Fig. 5*, the graphic representation, according to which the absorption of ammonia by liquid base takes place at temperatures of 32°, 70° and 150°, and absolute

TABLE III.—SHOWING THE ABSORPTION OF AMMONIA BY WATER AT DIFFERENT TEMPERATURES AND PRESSURES, ACCORDING TO SIMS.

One Volume of Water absorbs the Following Quantities of Ammonia:

Absolute Pressure in Pounds per Square Inch.	32° F.		68° F.		104° F.		212° F.	
	Grammes.	Volumes.	Grammes.	Volumes.	Grammes.	Volumes.	Grammes.	Volumes.
14·67	0·899	1,180	0·518	683	0·338	443	0·074	97
15·44	0·937	1,231	0·535	703	0·349	458	0·078	102
16·41	0·980	1,287	0·556	730	0·363	476	0·083	109
17·37	1·029	1,351	0·574	754	0·378	496	0·088	115
18·34	1·077	1,414	0·594	781	0·391	513	0·092	120
19·30	1·126	1,478	0·613	805	0.404	531	0·096	126
20·27	1·177	1,546	0·632	830	0·414	543	0·101	132
21·23	1·230	1,615	0·651	855	0·425	558	0·106	139
22·19	1·283	1,685	0·669	878	0·434	570	0·110	140
23·16	1·336	1,754	0·685	894	0·445	584	0·115	151
24·13	1·388	1,823	0·704	924	0·454	596	0·120	157
25·09	1·442	1,894	0·722	948	0·463	609	0·125	164
26·06	1·496	1,965	0·741	973	0·472	619	0.130	170
27·02	1·549	2,034	0·761	999	0·479	629	0·135	177
27·99	1·603	2,105	0·780	1,023	0·486	638	—	—
28·95	1·656	2,175	0·801	1,052	0·493	647	—	—
30·88	1·758	2,309	0·842	1,106	0·511	671	—	—
32·81	1·861	2,444	0·881	1,157	0·530	696	—	—
34·74	1·966	2,582	0·919	1,207	0·547	718	—	—
36·67	2·070	2,718	0·955	1,254	0·565	742	—	—
38·60	—	—	0·992	1,302	0·579	764	—	—
40·53	—	—	—	—	0·594	780	—	—

pressures from one to four atmospheres, the full lines showing the amount of ammonia in reality absorbed, the dotted lines showing the amount which ought to be absorbed. It will be seen that, contrary to the absorption of ammonia by water, the absorption of ammonia by liquid base is

according to the above-mentioned law, the differences existing between the two lines of 70° and 150° being due to error of observation. At 32° the absorption seemingly does not follow at all the law for the absorption of gases, the full line diverging upwards of about two and one-quarter atmospheres more and more from the dotted line. But this is only due to the fact that the ammonia comes nearer and nearer the point where it liquefies (the liquefying point of ammonia at 32° taking place at an absolute pressure of

TABLE IV.—SHOWING THE ABSORPTION OF AMMONIA BY LIQUID BASE AT DIFFERENT TEMPERATURES AND ATMOSPHERIC PRESSURE.

Temperature in ° F.	1 Vol. of Liquid Base absorbs Volumes of Ammonia, Calculated at 32° and Normal Pressure.	Temperature in ° F.	1 Vol. of Liquid Base absorbs Volumes of Ammonia, Calculated at 32° and Normal Pressure.
	volumes.		*volumes.*
32	3·139	150	1·243
40	2·880	160	1·117
50	2·592	170	1·012
60	2·383	190	0·898
70	2·197	210	0·873
80	2·091	232	0·751
90	1·950	250	0·700
100	1·824	260	0·680
110	1·714	270	0·661
120	1·588	283	0·638
130	1·465	300	0·611
140	1·308		

4·215 atmospheres or 61·834 pounds), and the amount of any gas absorbed by a liquid always exceeds the amount which ought to be absorbed, as soon as the temperature of the gas comes near its liquefying point.

The tests were made in the following manner:

Flask *A B C* (see *Fig. 1*) that is to be filled with liquid base is made of strong glass. It contains up to the beginning of its neck 555 ccm., the neck itself which is divided into cubic centimetres, contains 45 ccm., the whole contents of the flask thus being 600 ccm. It is filled with liquid base

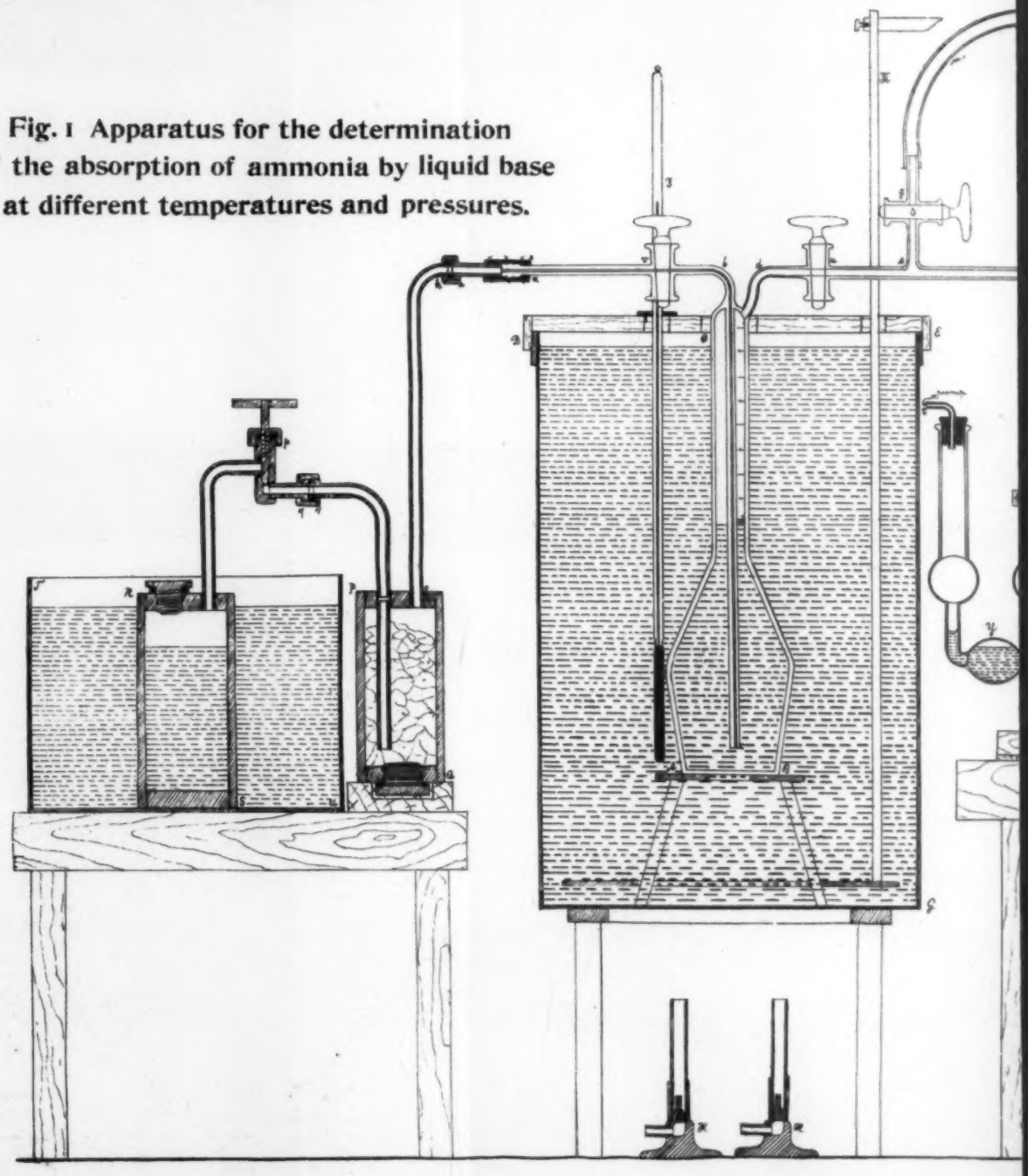
by means of a siphon to such an extent that afterwards, if heated up to the temperature at which the test is to take place, the liquid base reaches to the lower part of the graduated neck. Flask *A B C* is put on a support in the covered sheet-iron tank *D E F G*, which is filled with linseed-oil or water and can be heated up by means of the burners *H H*

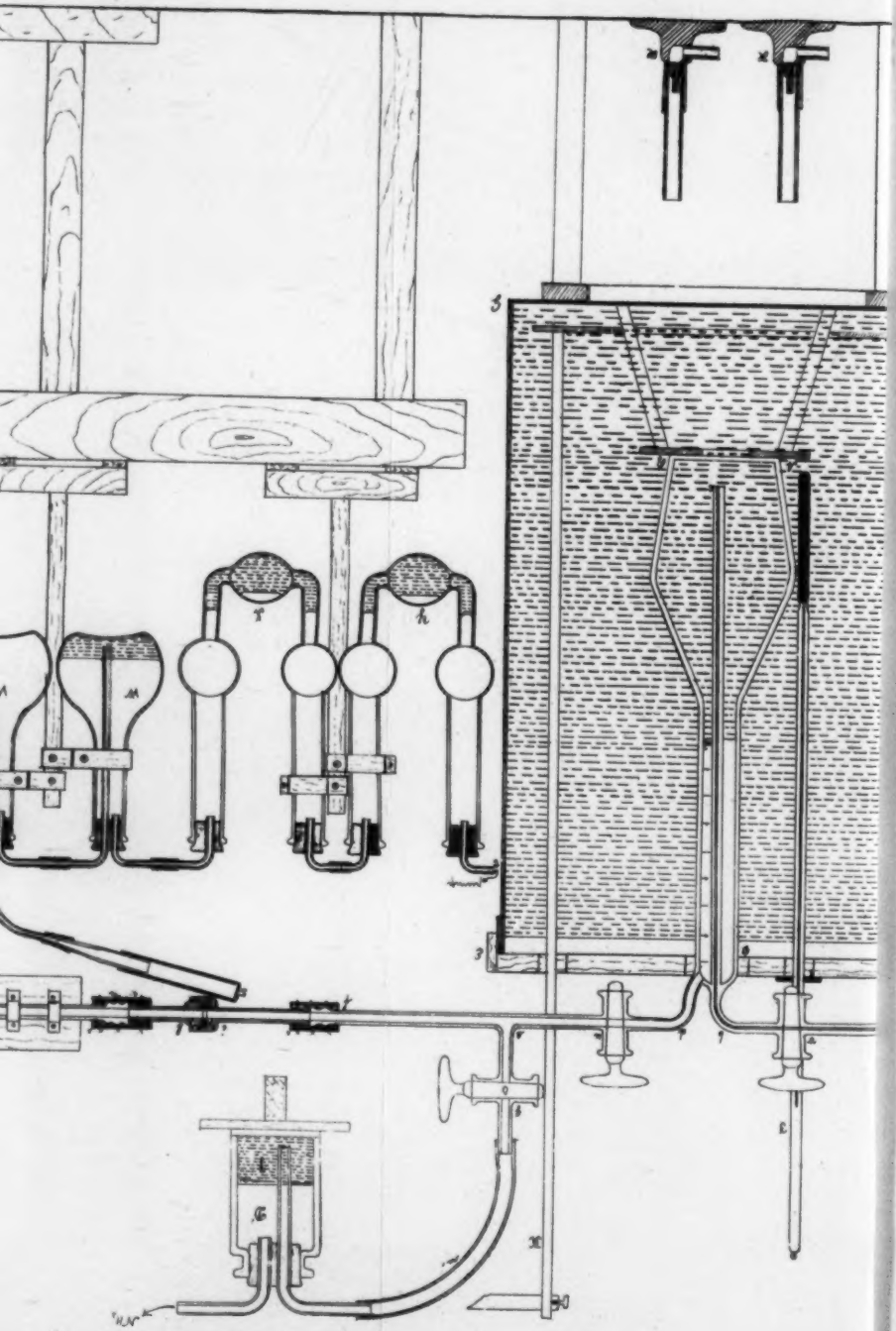
TABLE V.—SHOWING THE ABSORPTION OF AMMONIA BY LIQUID BASE AT DIFFERENT TEMPERATURES AND PRESSURES.

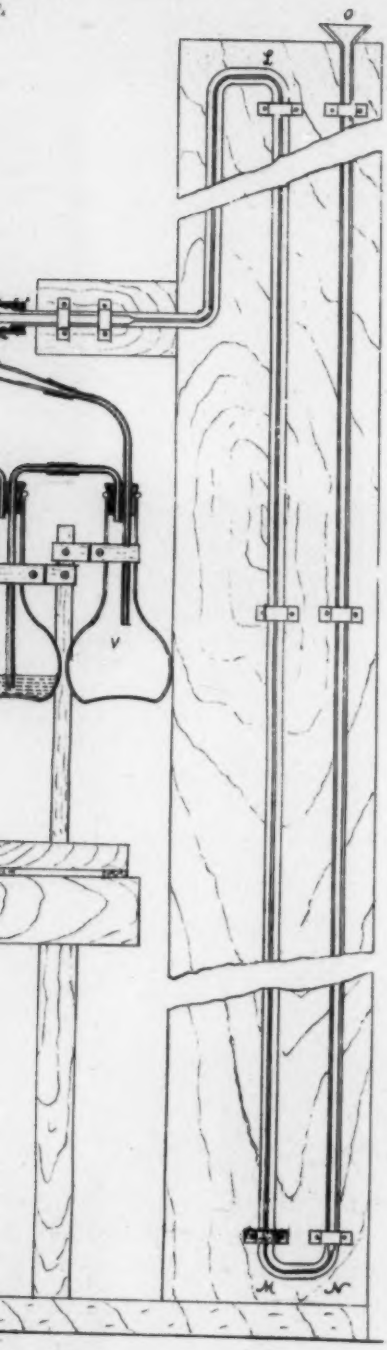
Absolute Pressure Expressed in Pounds per Square Inch.	1 Vol. of Liquid Base absorbs Volumes of Ammonia, Calculated at 32° and Normal Pressure.					
	at 32° F.		at 70° F.		at 150° F.	
	Volumes of Ammonia in Reality Absorbed.	Volumes which ought to be Absorbed.	Volumes of Ammonia in Reality Absorbed.	Volumes which ought to be Absorbed.	Volumes of Ammonia in Reality Absorbed.	Volumes which ought to be Absorbed.
14·67	3·139	—	2·197	—	1·243	—
18·34	3·862	3·924	2·862	2·746	1·477	1·554
22·00	4·914	4·708	3·399	3·295	1·811	1·864
25·67	5·677	5·493	3·946	3·845	2·053	2·175
29·34	6·333	6·278	4·442	4·394	2·387	2·486
33·01	7·354	7·063	5·041	4·943	2·671	2·797
36·67	8·039	7·847	5·657	5·492	2·959	3·107
40·34	8·933	8·632	6·219	6·042	3·247	3·418
44·01	10·046	9·417	6·599	6·591	3·536	3·729
47·68	10·990	10·201	7·344	7·140	3·841	4·039
51·34	12·338	10·986	7·724	7·692	4·169	4·350
55·01	13·497	11·771	8·352	8·239	4·467	4·661
58·68	15·655	12·566	8·529	8·788	4·692	4·972
146·70		calculated.				12·430

to any desired temperature, controlled by the thermometer *I* and kept uniform in all parts by means of the agitator *K*. The pipe *a b c* is capillary, the diameter of the pipes *d e f* and *e g* four mm. inside. Cocks *v* and *u* are common stop-cocks, cock *g* the plug of which has a wedge-shaped perforation; allows to regulate the quantity of ammonia escaping out of the flask *A B C* in the minutest manner. From *g* the escaping

Fig. 1 Apparatus for the determination of the absorption of ammonia by liquid base at different temperatures and pressures.



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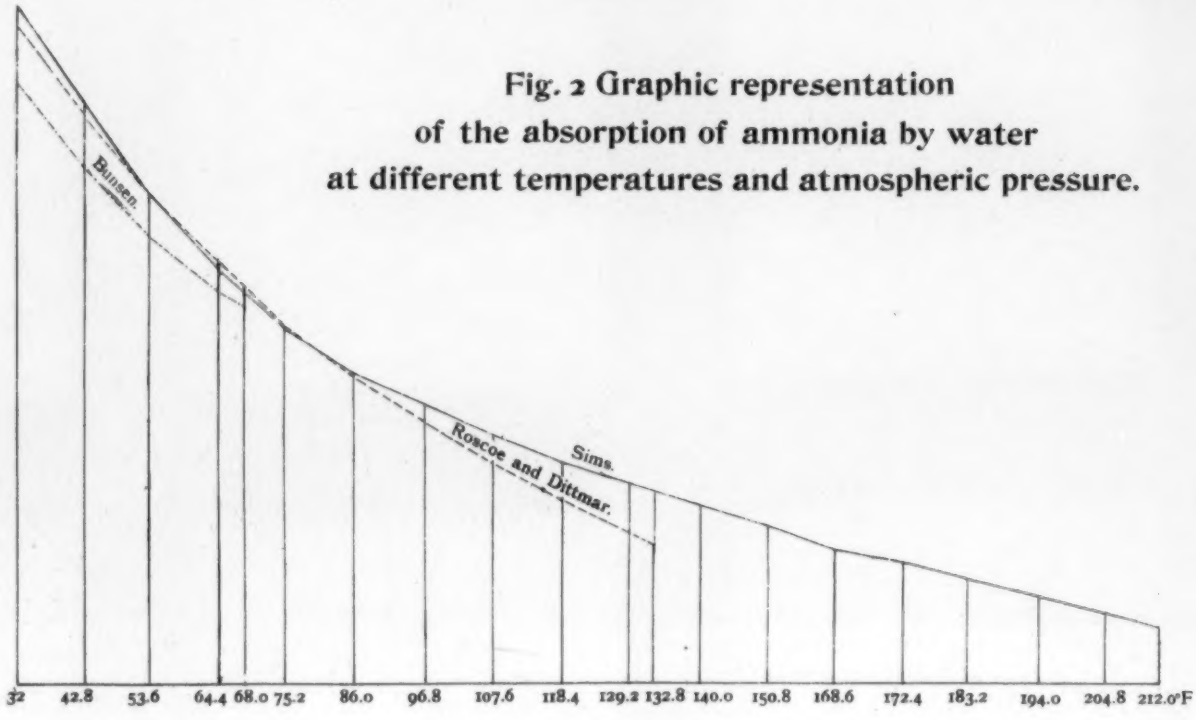


Fig. 2 Graphic representation of the absorption of ammonia by water at different temperatures and atmospheric pressure.

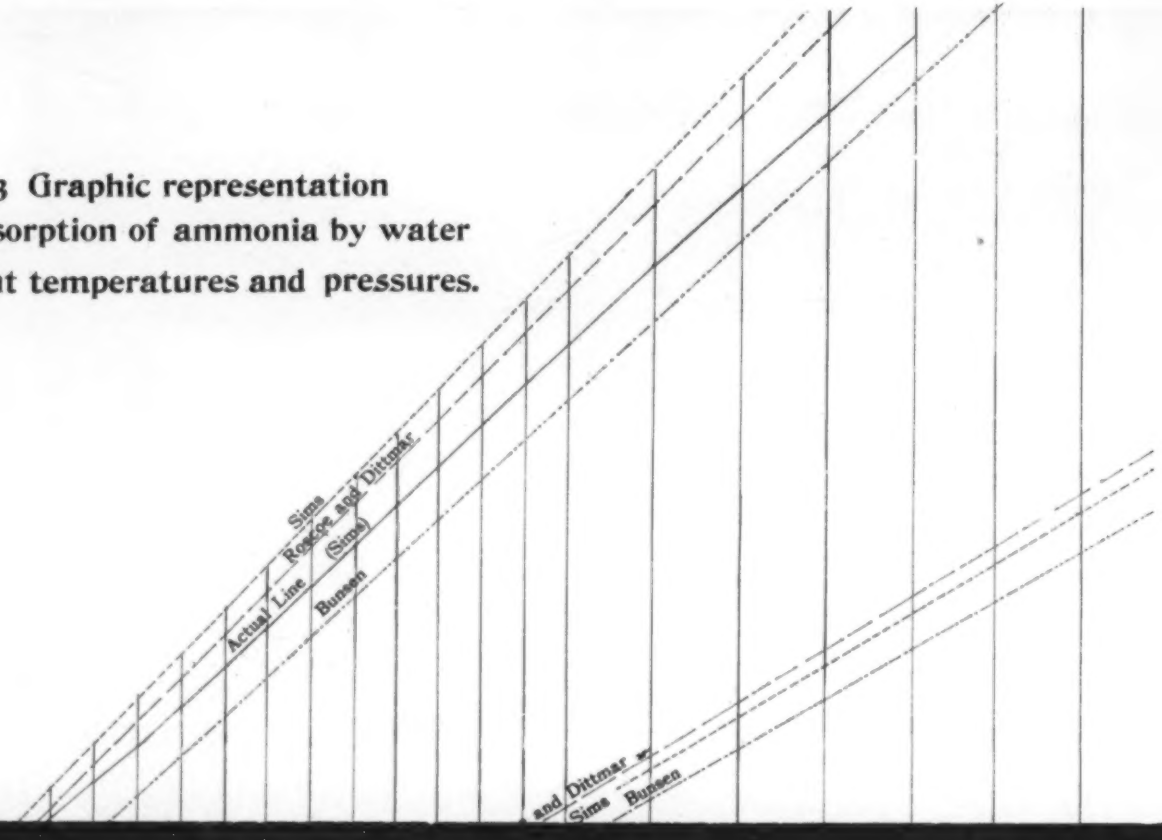
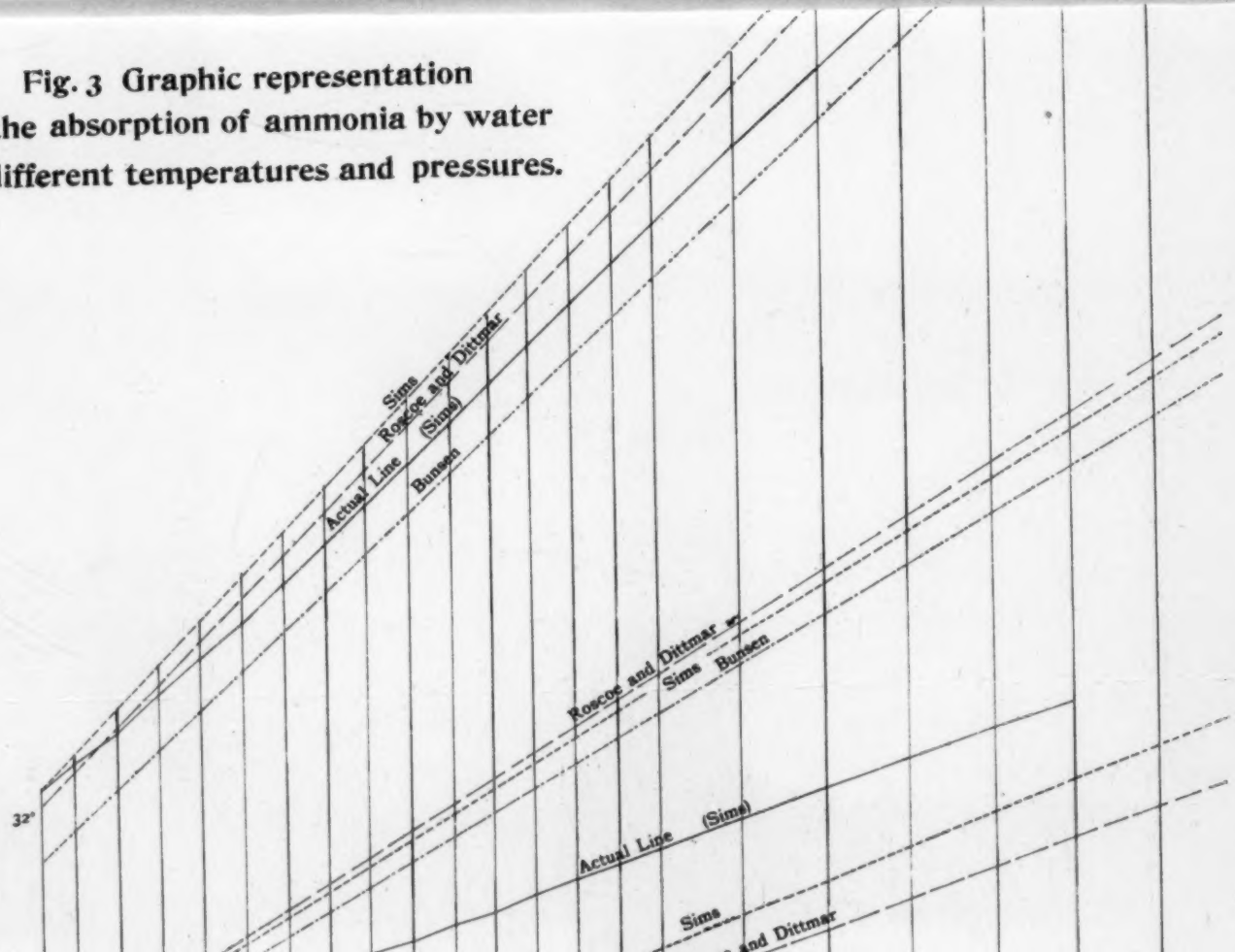
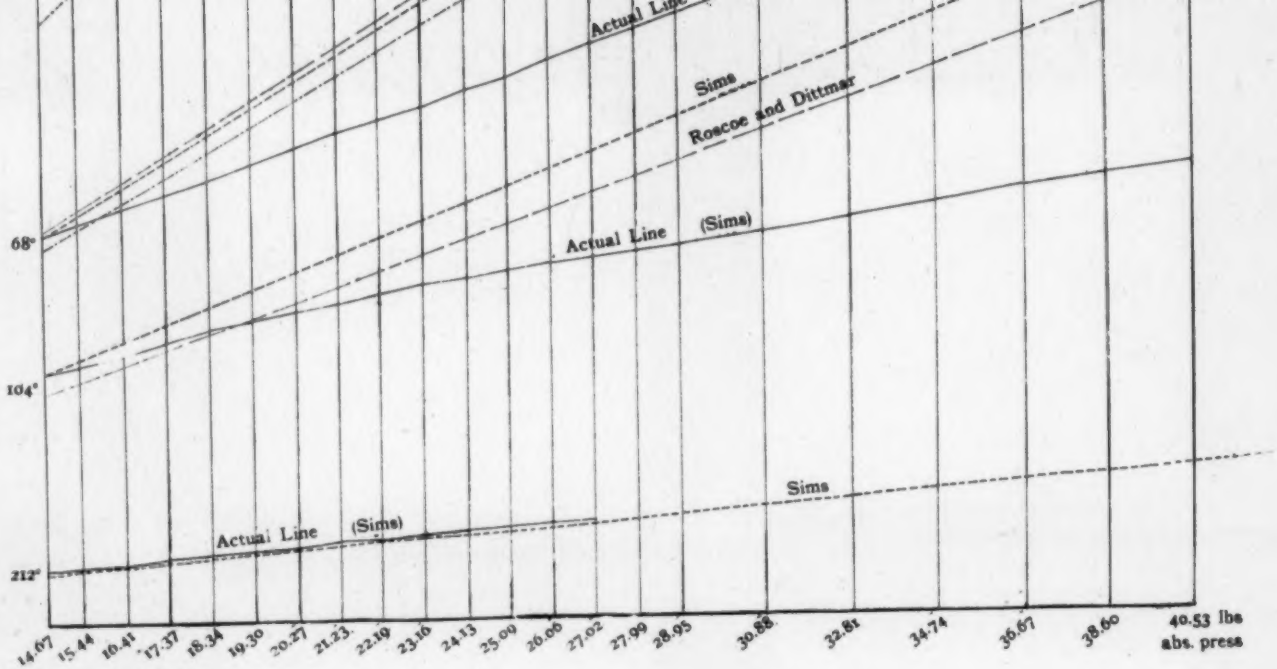


Fig. 3 Graphic representation of the absorption of ammonia by water at different temperatures and pressures.

Fig. 3 Graphic representation of the absorption of ammonia by water at different temperatures and pressures.




Actual Line
Sims
Roscoe and Dittmar
68°
Actual Line (Sims)
104°
Sims
Actual Line (Sims)
212°
14.67
15.44
16.41
17.37
18.34
19.30
20.27
21.23
22.19
23.16
24.13
25.09
26.06
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27.99
28.95
30.88
32.81
34.74
36.67
38.60
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abs. press

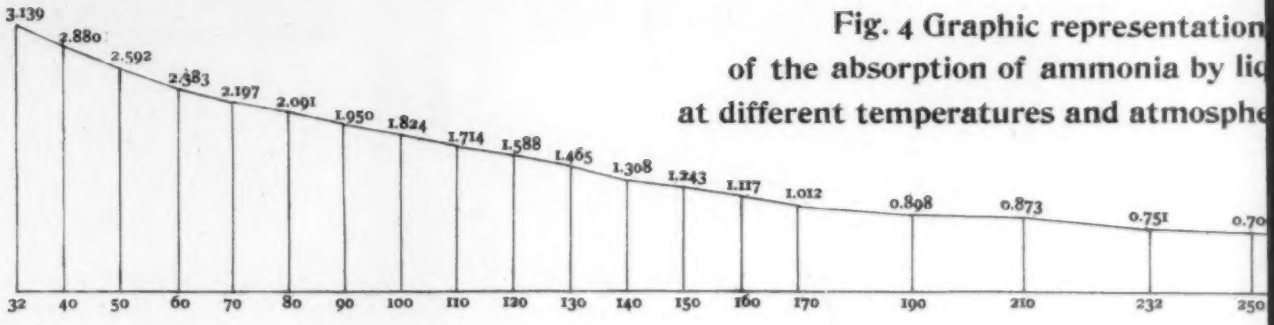


Fig. 4 Graphic representation of the absorption of ammonia by liq at different temperatures and atmosphe

Fig. 5 Graphic representation of the absorption of ammonia by liquid base at different temperatures and pressures.

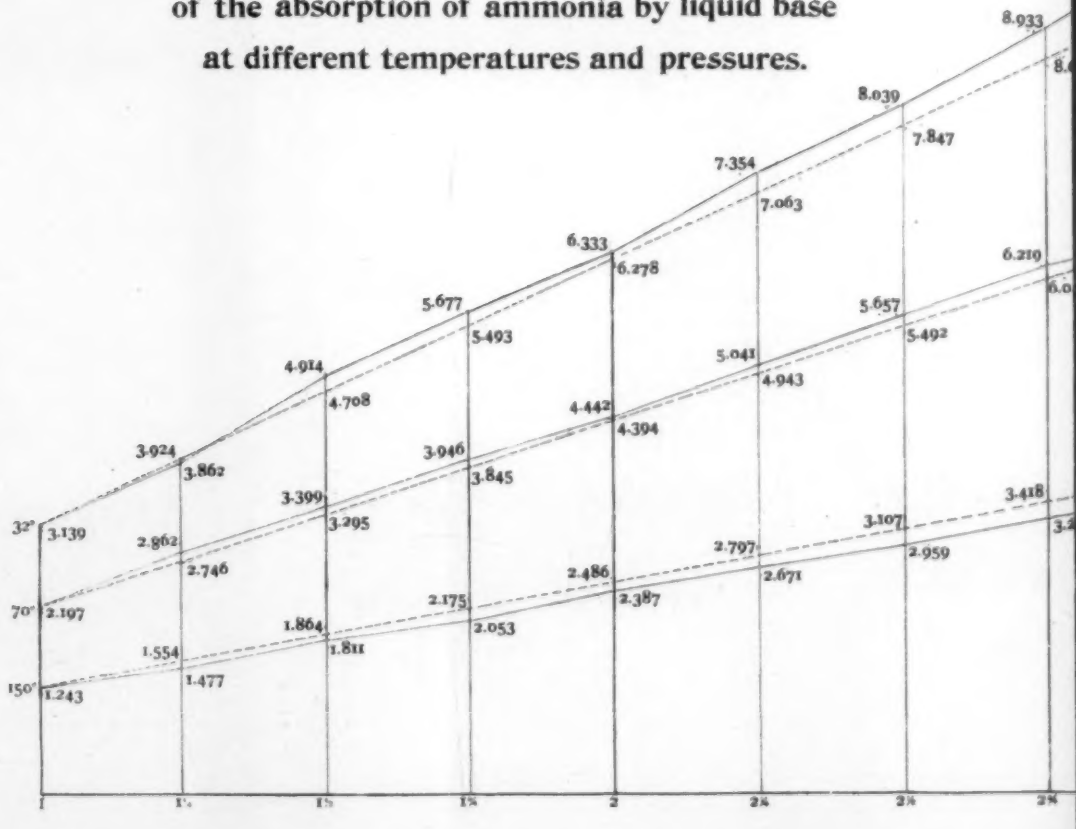
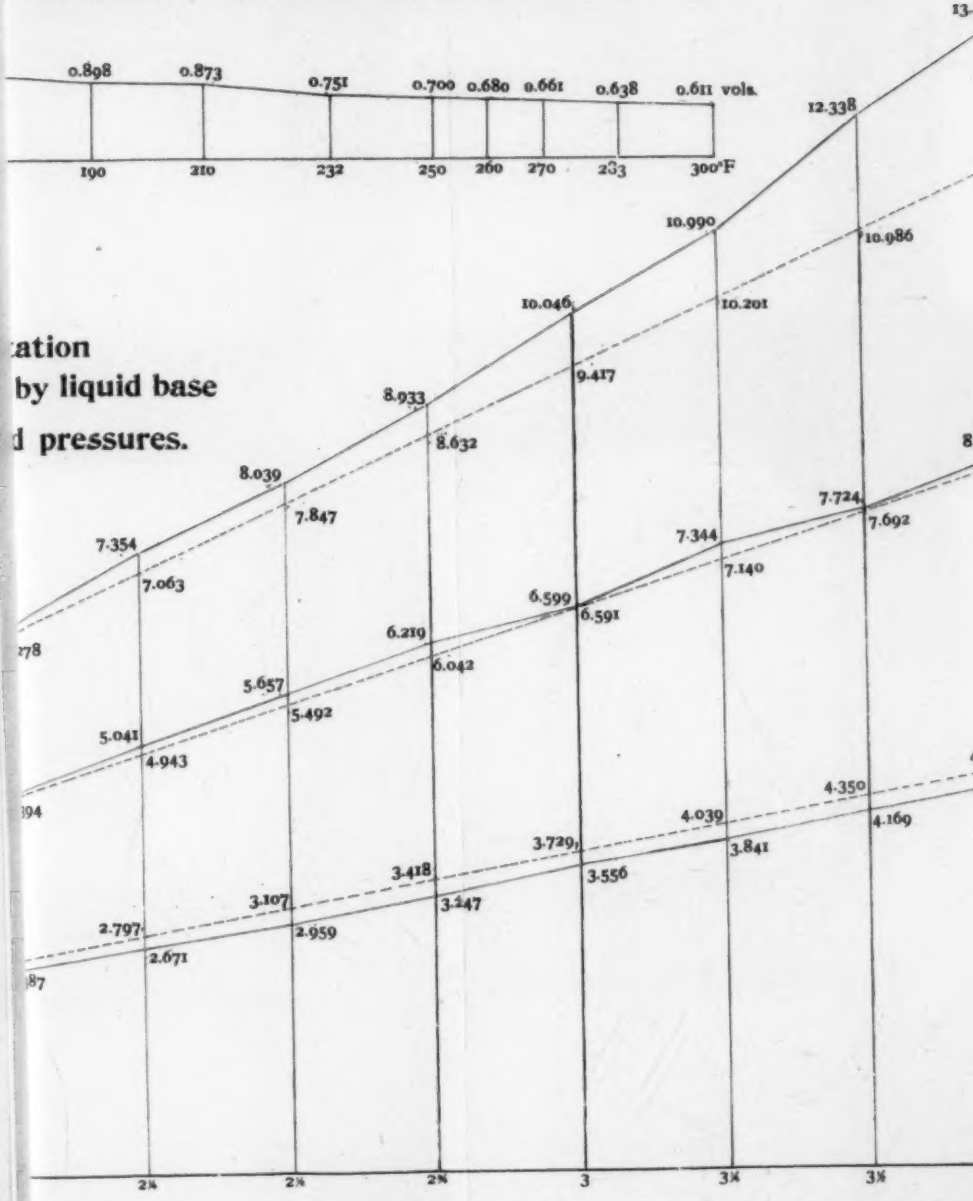
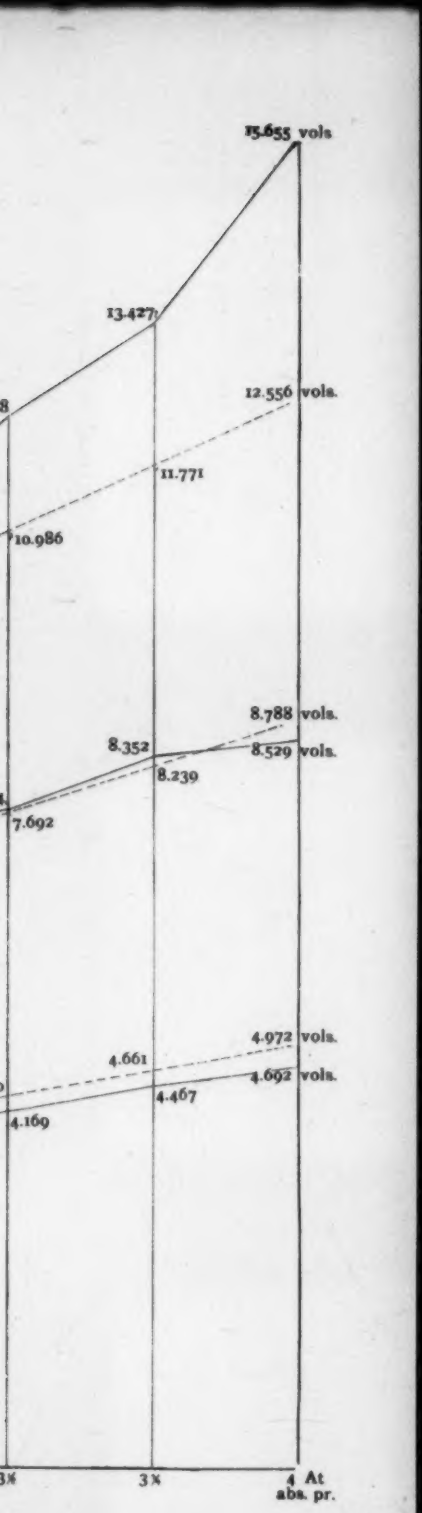


Fig. 4 Graphic representation
absorption of ammonia by liquid base
ıt temperatures and atmospheric pressure.




15.655 vols
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gas passes through a stratum of mineral oil in D', and from there into the atmosphere. The purpose this bottle D' is intended for is that by the velocity with which the bubbles of ammonia pass through the oil in D', the velocity of the current of ammonia passing through flask $A\ B\ C$ can be judged. The pipe ends a and f are provided with bulbs and by means of strong pieces of rubber-hose (the resistance of which is strengthened by brass-sheathings wrapped over them) connected with two short pieces of iron pipe which are provided on their other ends h and i with a thread and a nut, fitting the nut k and the thread l, respectively, tightly by means of washers. The nut k is at the end of the pipe $k\ o$ terminating into the top of tank $P\ Q$ which is filled with pieces of sodium hydrate. The ammonia developed in tank $R\ S$ passes through the contents of tank $P\ Q$, and is thus freed of any moisture which may be present. In order to make the development of the ammonia constant and thus avoid as much as possible any sudden turbulent eruptions of the same, tank $R\ S$ is put in cold water contained in tank $T\ U$. Cock p is of such a construction as to allow us to regulate the quantity of ammonia entering flask $A\ B\ C$ in the minutest manner. The other end of the iron pipe $l\ m$ by means of a strong piece of rubber-hose (again strengthened by brass-sheathing) is connected with the end n of the mercury gauge $L\ M\ N\ O$. Pipes $L\ M$ and $N\ O$ being about two and one-half metres long, an absolute pressure of four atmospheres can be obtained without having the mercury in leg $L\ M$ go too far down to the bend M, and thus without being exposed to the liability of one of the above-mentioned uncontrollable eruptions of the ammonia forcing the mercury entirely out of leg $L\ M$, and thus spoiling the whole test. Pipe $L\ M$ being capillary, the diameter of $N\ O$ being five mm. inside, an oscillation of a few millimetres up or down of the mercury in $L\ M$ is hardly noticeable in $O\ N$, and thus by regulating cocks p and g the pressure prevailing during the test can be kept constant within a few millimetres.

When the contents of flask $A\ B\ C$ have the desired temperature, the whole apparatus is put together as shown in

Fig. 1. Ammonia is allowed to pass through the oil until all air in the neck of *A B C*, in bottle *D'* and in the gauge, is displaced by ammonia, and then mercury filled into the gauge to a convenient height. If the test is to be made at atmospheric pressure, nothing is to be done but to regulate the current of ammonia in such a way that the mercury column is at the same height in both legs of the gauge, but the pipe *d e g* having a much larger diameter than *a b c*, hardly any regulation of cock *p* is necessary. If the test is to be made at higher pressure the two cocks *p* and *g* are handled until the pressure indicated by the gauge is the desired one, it being taken care that a properly strong current of ammonia escapes through *D'*. According to the prevailing temperature and pressure it takes from one-half to two hours, until the liquid base is entirely saturated with ammonia. This condition being obtained, cocks *u* and *v* are closed in the very same moment, and *k* is disconnected from *h*. Then *i* having been disconnected from *l* and by means of the rubber-hose *s* having been connected to the absorbing apparatus, cock *u* is opened. As soon as the first turbulent escaping of ammonia is over, cock *v* is opened and a slow current of pure air is conducted through the whole apparatus, the linseed-oil in tank *D E F G* being heated up during this time at about 300°. Thus all ammonia that was absorbed by liquid base is conducted into the absorbing apparatus, where it is transformed into ammonium chloride, *W X* and *Y* being filled with diluted muriatic acid. If the test has been made at higher pressure and the absorbed ammonia is drawn off, larger or smaller quantities of liquid base are always forced out of flask *A B C*, and these are retained in the empty bottle *V*, thus not interfering with the formation of pure ammonium chloride in *W X* and *Y*. It takes about three hours until the last traces of ammonia are obtained in the receivers. The weight of the ammonia which had been absorbed by the oil and from it the volume of the same calculated at 32° and normal pressure, is determined in the usual way. From the volume thus obtained the volume of ammonia which at the end of the test was above the liquid base in the graduated neck of flask *A B C*,

is to be subtracted. As it is under the pressure and temperature, at which the test was made, its volume at 32° and normal pressure is to be calculated. Then by dividing the cubic centimetres of ammonia really absorbed by the oil, by the cubic centimetres of liquid base used in the test, the volume of ammonia absorbed by the unit of liquid base is obtained. For mechanical reasons, it is practically impossible to keep the pressure exactly at the point at which the test was intended to be made, and the absorption took place at a pressure of a few millimetres more or less in almost all tests made. From the results obtained with the pressures prevailing we obtain the figures for the pressures intended by application of the above-cited law for the absorption of gases by liquids at different pressures. The following is an example how this calculation was made:

Temperature at which the test was made, 150°; absolute pressure prevailing, 1906·0 mm.; absolute pressure intended, 1900·0 mm. = 2½ atmospheres; volume of liquid base used in the test, 559·0 ccm. at 150°. Consequently at the end of the test 600 — 559 = 41·0 ccm. of ammonia at 1906·0 mm., absolute pressure, and 150° are above the oil. These are equal to 82·7 ccm. at 32° and normal pressure.

The weight of ammonium chloride yielded is 4·2050 grammes = 1·3360 grammes = 1754·6 ccm. of ammonia at 32° and normal pressure. The 82·7 ccm. of ammonia abovementioned being subtracted, 1754·6 — 82·7 = 1671·9 ccm. of ammonia were in reality absorbed by the 559·0 ccm. of liquid base or 2·990 volumes by the unit. If 2·990 volumes are absorbed at 1906·0 mm.,

$$\frac{2{\cdot}990 \times 1900{\cdot}0}{1906{\cdot}0} = 2{\cdot}981 \text{ volumes}$$

are absorbed at an absolute pressure of 1900·0 mm.

By calculations based on the above data, Mr. A. Siebert, Superintending Engineer of the De La Vergne Refrigerating Machine Company, found that the volumes of ammonia absorbed at temperatures between 80° and 300° F. can approximately be calculated by the formula:

$$d = 3{\cdot}139 - 0{\cdot}023972\ (t - 32°) + 0{\cdot}00008073\ (t - 32°)^2 - 0{\cdot}0000000988\ (t - 32°)^3$$

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, March 1, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 1, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, thirty members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing and clerical work, which were approved and ordered paid.

The Committee on Admissions reported one election to membership since last meeting.

Mr. C. W. Pike read a paper on "The Constant Shunt Method for the Measurement of Continuous Currents," with blackboard illustration. Referred for publication. In discussion thereon, Mr. Carl Hering stated that this method had been used successfully at the Munich Exhibition of 1882, and by himself at the Institute's Electrical Exhibition of 1884. In the latter case copper wire was used throughout, making the rate of temperature variation more regular. Mr. Willyoung also stated that he had used this method satisfactorily.

Prof. E. J. Houston read a paper on "Cerebral Radiation" which was discussed at some length and referred for publication.

Mr. Carl Hering gave some data submitted by the Oerlikon Works for the power-transmission plant at Niagara. The current furnished would be equally suitable for motors, arc and incandescent lights. The dynamo is a three-phase, separately-excited machine of 5,000 horse-power, and ninety-six per cent. efficiency. Its drum armature is made up of copper bars, is ten feet in diameter, and, running at 250 revolutions per minute, will furnish a current in each of the three coils of 2,000 ampères, at 600 to 700 volts. The current from each machine feeds through two 2,500 horse-power transformers, capable of reducing from 25,000 volts. Cost of the line to be $20,000 for 32,000 metres, to carry up to 10,000 horse-power. Total estimated cost, including generators, exciters, transformers and lines, to be $180,000.

A query from the Question-Box regarding the temperature coëfficient of a Weston voltmeter was discussed at some length, and satisfactorily answered.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

RESISTANCE STANDARDS: THEIR MANUFACTURE AND ADJUSTMENT.

By Elmer G. Willyoung.

[*Read at the stated meeting, held November 3, 1891.*]

I shall speak to you for a very brief time this evening on the subject of electrical standards of resistance. The standard of resistance is, to my mind, by far the most valuable standard with which we have to do in actual work. Considering only the quantities involved directly in Ohm's law, which are about the only quantities of any particular value or meaning to four electricians out of five, the standard of resistance is almost the *only material* standard which we can possess. The unit of current is a standard but it is a standard which only exists by definition and is not an actual tangible and physical thing, while the standard of E.M.F. which shall give an exact unit or multiple of a unit is yet to be discovered; a standard cell, to be sure, giving a definite E.M.F. at a definite temperature and whose rate of variation with temperature is accurately known, is now a comparatively easy thing to secure, but the care necessary in its use together with the decimal value of its E.M.F. are both considerably against its being rated as high, practically, as the standard of resistance. It must also be borne in mind that, having a standard of resistance, we may obtain the value of any E.M.F. by the solving of $E = CR$ where C is known from the amount of electrolytic deposition taking place in a given time out of a suitable solution; the amount of copper, silver, or other metal deposited out of such a solution in a given time by a given current being always a definite and exact one to be found in any text-book upon the subject.

The standard of resistance, as generally known, is a length of wire of one kind or another, wound upon a spool, mounted in a convenient case to protect it from injury and moisture, and having its resistance at some given tempera-

ture definitely determined; a true standard also has its rate of variation of resistance for change of temperature accurately known. Sometimes one coil is mounted up alone and sometimes many coils of different values are put up in the same mounting.

In the manufacture of standards of resistance a great many qualities are required of the resistance wire which shall be used. It should have high specific resistance, in order that the standard may not have too much bulk; it should have as small a temperature coëfficient of resistance as possible, in order that its value may be easily obtained at any reasonable temperature without the making of troublesome calculations; it must not change its resistance in time; it must not be oxidizable by the air or by the medium in which it may be enclosed, since this would change the constitution and hence the resistance of the wire; and it must be of a hardness suitable for handling in manufacture and adjustment without injury. The requirement of high specific resistance immediately compels us to reject copper, iron, aluminum, silver, and all other pure metals except lead, antimony and bismuth. The softness, difficulty of working, and high temperature coëfficient as well as many other reasons would throw these last three out of the account. The matter of temperature coëfficient alone, in fact, would compel us to reject all pure metals since they all increase roughly about twenty-five per cent. in resistance between 0° and 100° C., except iron, which increases about forty per cent. We are, therefore, led to try alloys. Dr. Matthiessen, chairman of the sub-committee (of the Committee on Electrical Standards of the British Association), from 1862–65, having in charge the investigation of the properties of wires with reference to the selection of a suitable one to be used in the standard of resistance, decided upon by the British Association and now known as the B. A. Ohm, examined very exhaustively a large number of wires, among which were pure iron, silver, copper, thallium and other metals, and a great many alloys; he finally concluded that silver alloyed with 33·4 per cent. of platinum was the best alloy obtainable. This alloy, known as plati-

num silver, is still used by English makers; it has a specific resistance of twenty-four microhms and a per cent. variation per degree C. of $\frac{31}{1000}$. In selecting this alloy we see that the requirements of high specific resistance and low temperature coëfficient have both been observed, the resistance of platinum silver being about sixteen times that of copper and its temperature coëfficient less than $\frac{1}{100}$ that of copper.

With reference to the constancy of resistance in wires it may be well to mention that many metals and alloys seem to alter in electrical resistance with time, or on being subjected to change of temperature. In an investigation carried on by J. Bergmann, a German electrician, in the latter part of 1889, he reports that, after raising to and maintaining at 300° C. for one hour and then cooling, the resistance of several substances changed as follows:

	Per Cent.
Copper decreased,	2·4
Aluminum "	5·0
Magnesium "	6·8
Zinc "	2·4
German-silver increased,	$\frac{2}{10}$

Mr. Tomlinson, a little earlier, found a somewhat similar result in the case of iron wire, which decreased in resistance about one-quarter per cent. after several heatings to 100° C., and subsequent cooling. Dr. Matthiessen, in the investigations previously alluded to, found a considerable time change in a number of the alloys and wires, which he experimented upon. It may be of interest to state here that three of the original platinum-silver coils determined by the British Association through Dr. Matthiessen and his colleagues at the time of the adoption of the B. A. Ohm were found last year, when carefully examined, to have developed an increase of resistance of about six parts in 10,000, or about $\frac{6}{100}$ per cent., quite an appreciable amount as standards go. The committee having these last comparisons in charge suggested that this change in resistance was only temporary, and due to strains in the wire produced by lowering it to 0° C., at which temperature the measurements were made; they have, however, not yet been able to verify this idea. A time change is, however, to be noted in a large

number of metals and alloys where strains are not taking place. This time change in resistance, as Dr. Matthiessen suggested, is probably very largely due to a gradual annealing effect, as it is particularly noticeable in hard-drawn wires. It has also been observed to be in a marked degree a property of wires containing zinc and to be lacking, except to a very small extent, in wires free from zinc; here it is possible that zinc may gradually crystallize out, since it does easily crystallize, and the homogeneity of the wire thus being altered, the change in resistance may be accounted for.

It is almost self-evident that the resistance of a metal or alloy is a function of its density; hence, all causes tending to change the density of the resistance metal will also tend to change its resistance. It is quite reasonable to expect, therefore, that an increase of resistance should be observed after a wire is wound upon a spool. A wire wound up on a spool not over eight times its own diameter will increase from one-half to two per cent. in resistance; a part of this increased resistance is due to the increased hardness caused on the inside of each turn, by the bending stress, and hence gradually falls away as the wire slowly anneals. For this reason, it is unsafe to send out a resistance standard as correct until several months have elapsed after winding.

Several years ago a wire was brought out in England known as "platinoid." It was said to be an alloy composed of ordinary German-silver with one or two per cent. of metallic tungsten added. It has a specific resistance of about thirty-two microhms and a temperature coëfficient of $\frac{22}{100}$ per cent. per degree Centigrade. I have analyzed this several times but have never been able to detect any tungsten; two or three friends have done the same with the same result. Whether or not any tungsten is used as the wire is now made, is, therefore, not certain. During the week since reading this paper, I have been informed by an electrician that the tungsten "burns out" in the process of manufacture. The properties of this alloy are, however, about as reported. It is nearly as cheap as German-silver, and during the time over which my own

observations have extended shows no time change; at least if any change has taken place in the coils in our possession, is has been by less than $\frac{1}{100}$ per cent. The wire is hard, practically non-oxidizable and easily handled. It is now being used in all the standards sent out by Queen & Co., and proves satisfactory in every way. I have here in my hand a wire recently sent me by the Aluminum Brass and Bronze Company, of Bridgeport, Conn., and claimed by the manufacturers to have thirty-five times the resistance of copper together with an extremely small temperature coëfficient, less than $\frac{1}{10}$ that of German-silver. I have not had an opportunity to test the accuracy of these statements as yet, having been too busy with other work, but hope soon to be able to do so. According to the *Electrical Engineer*, of October 21, 1891, there is also claimed for this wire a tensile strength of 70,000 to 100,000 pounds per square inch, with eighty twists in six inches, and with a lower resistance, a tensile strength up to 140,000 pounds per square inch You see it is of a pale-rose color and looks as if it might contain considerable copper. I suspect it is a variety of manganese-copper made up of about seventy per cent. of copper and thirty per cent. of manganese, with perhaps a small percentage of nickel. Mr. Edward Weston experimented on some of these alloys a couple of years ago and found one of them to have a negative temperature coëfficient; his statement to that effect was received with considerable incredulity at the time, but has since been thoroughly verified. According to Drs. Feusner and St. Lindeck, in *Zeitschrift für Instrumenten Kunde*, February, 1891, an alloy composed of seventy per cent. copper and thirty per cent. manganese had a resistance of about five times that of German-silver and a temperature coëfficient of but $\frac{4}{1000}$ per cent. per degree Centigrade, while an alloy of seventy-three per cent. copper, three per cent. nickel, and twenty-four per cent. manganese had a specific resistance a little less than three times that of German-silver, and a *negative* temperature coëfficient of $\frac{3}{1000}$ per cent. We see, hence, that it ought to be entirely possible to obtain a wire having a zero coëfficient, *i. e.*, not changing resistance at all for change of

temperature by properly combining the constituent metals of this alloy. The obtaining of such an invariable standard is a "consummation devoutly to be wished" in electrical work as accurate work is very troublesome and tedious where long decimal coëfficients have to be applied, and this becomes particularly the case where several sets of coils are used in the same investigation having different temperature coëfficients. Dr. E. S. Nichols, of Cornell University, and others have made successful attempts to obtain resistances having a zero coëfficient working along another line; they have taken a rod of carbon and soldered to its extremities a length of wire of some metal or alloy; since carbon decreases and wires increase their resistance with rising temperature, it is evident that by using a suitable wire and proper proportions a combination might be found which when placed in a circuit in parallel would remain of the same resistance at any temperature. The difficulty of soldering to carbon as also the care necessary in adjusting prevent, however, such resistances from becoming commercial possibilities; the carbon is also too sensitive to changes of pressure and to strains.

A strictly standard resistance is, according to the practice of the best makers, adjusted to anything within from $\frac{1}{10}$ to $\frac{1}{100}$ per cent. of absolute accuracy. A *single* coil would not be considered a "standard coil" unless it were accurate within from $\frac{1}{50}$ to $\frac{1}{100}$ per cent. absolute accuracy. To obtain this high accuracy of adjustment it is easily seen that very exact methods of measurement must be employed; should we attempt to measure an inch within this limit of error, the error could not be over $\frac{1}{10000}$ inch, an exceedingly small quantity. Various methods have been suggested and employed by different parties at different times. An apparatus designed by Prof. Fleeming Jenkin, and used somewhat by the British Association Committee in 1862, consisted of essentially, an ordinary Wheatstone's Bridge with the connection between two adjacent arms, consisting of a short, straight length of resistance wire. If, now, one galvanometer contact be on this straight wire and the other at the junction of the two opposite arms of the bridge, and *S*, one

of these opposite arms, be the coil to be adjusted to R, the other of the opposite arms, and the arms adjacent to the straight wire be designated C and A we will have

$$\frac{C}{A} = \frac{R}{S}$$

we now interchange R and S and have

$$\frac{C}{A} = \frac{S}{R}$$

this will demand a new position of the galvanometer contact upon the straight wire and the distance moved over on the straight wire is a measure of the difference in resistance between R and S.

Suppose that C and A each have 100 inches of the same wire as the straight wire and that we have had to move over one inch in reversing R and S, then R and S agree within one per cent. Now we adjust S closer to R and substitute for C and A two new coils C' and A' each of 1,000 inches wire. If now we again adjust so as to move over one inch in reversing we are within $\frac{1}{10}$ per cent. of accuracy; and so by continually adjusting S to R we may obtain gradually closer approximations to accuracy if we, at the same time, substitute other coils for C and A. But this process is, at the best, but a cut-and-try one and exceedingly tedious. A complete description of this method and convenient apparatus will be found on p. 38, of *Reports of Electrical Standards*, published by Spon.

I have here a piece of apparatus first designed several years ago during my student days. It is a modification of an arrangement devised by Prof. S. P. Thompson, and described in *Stewart & Gee*, 2d vol., p. 160. The one I have here was first suggested to me by Prof. H. S. Carhart, of Michigan University, and has since been somewhat modified by myself. If we take an ordinary slide wire bridge having four openings for coils at the back and (the slide wire being in front) fill these spaces, beginning at the left, with coils designated P R_1 R_2 and Q, respectively, connect the battery from between P and R_1 to between R_2 and Q, and the galvanometer from between R_1 and R_2 to a point on

the slide wire, we have substantially the method which is known as the Carey-Foster method. Designating the resistance of copper connector at the left by r_1 and of copper connector at the right by r_2 and letting P be the resistance of unit division of the wire.

$$\frac{R_1}{R_2} = \frac{P + r_1 + X_1 \rho}{Q + r_2 + (L - X_1)\rho} \tag{1}$$

where X_1 is the reading on the bridge wire and L the total number of divisions. Reverse the position of P and Q and we have

$$\frac{R_1}{R_2} = \frac{Q + r_1 + X_2 \rho}{P + r_2 + (L - X_2)\rho} \tag{2}$$

From (1) we have

$$\frac{R_1}{R_1 + R_2} = \frac{P + r_1 + X_1 \rho}{P + Q + r_1 + r_2 + L \rho} \tag{3}$$

and from (2) we have

$$\frac{R_1}{R_1 + R_2} = \frac{Q + r_1 + X_2 \rho}{P + Q + r_1 + r_2 + L \rho} \tag{4}$$

From (3) and (4) we get

$$Q + r_1 + X_2 \rho = P + r_1 + X_1 \rho$$

$$Q - P = \rho (X_1 - X_2)$$

which is an expression independent of the resistance of the end pieces of the bridge, being merely the resistance of that portion of the wire over which we must move in obtaining our two balances. Thompson's device is merely for quickly and conveniently interchanging coils P and Q; with it we must change the position of four copper connectors in four mercury cups; this is tedious and increases the danger of a change of temperature between the adjustments. The modification which I have here has reduced these changes to two which can be almost instantly made. With this device and a carefully calibrated bridge wire it is an extremely simple matter to attain an accuracy of $\frac{1}{100}$ per cent., while much higher percentages of accuracy may be gotten with care. Of course, in this method the coils P

and Q must be at a definitely known temperature which shall not change during the taking of the two readings; hence, the two coils are placed in well stirred water or oil baths. The other coils R and S are wound together and left in the open air as, if they change at all, they will probably change about equally and the result be of no appreciable importance. This device is also the best thing to use in determining temperature coëfficients of wires; a length of wire is wound up on a spool, immersed in oil at a definite temperature and compared with a standard. The temperature of the oil is then raised and the resistance of the wire again determined; knowing the difference of temperature and the change of resistance the temperature coëfficient follows.

On the VARIABLE ACTION of TWO-COIL SOLENOIDS.

By Wm. S. Aldrich, Johns Hopkins University, Baltimore, Md.

[*Read at the meeting of the Electrical Section, held February 2, 1892.*]

The Two-coil Solenoid Electro-magnetic Mechanism produces a double-acting reciprocating movement of an iron core or plunger, when the coils are variably energized by a pulsating current, causing the induction to rise from zero to a maximum alternately in each coil. The action of the plunger under the influence of the two magnetic fields of force, other conditions being equal, will vary according to whether the two solenoids act with or against each other. The respective movements of the plunger are not only very different in each case, but the maximum pull in either direction towards the central line between the two coils is greater in the former arrangement than in the latter, as will be seen by referring to the plotted results of the experiments under these two conditions.

A preliminary experiment was made with a variable current obtained by an adjustable resistance, to determine the maximum pull, its variation, the movement of the plunger

when under maximum pull, and also when exerting no pull, or when in a position of equilibrium. In the experiments of which the results are shown graphically, the pulsating current was obtained by a rotating brush * moving around the commutator of a dynamo, and the action of the two coils was examined with reference to:

(1) The combination (the differential coil-and-plunger of Sylvanus P. Thompson's classification), consisting of the two solenoid coils as two parts of one coil, traversed by a pulsating current of variable intensity in each part, and giving rise to a resultant magnetic field from the combination of the two variable-intensity electro-magnetic stresses of like character, and constant in direction.

(2) The combination operating as two distinct solenoids, producing resultant stresses in the ether medium from the two variable-intensity electro-magnetic stresses of opposite character and constant in direction.

The Pulsating Current Obtained by Variable Potential through constant resistances, will give quite a steady pull and almost regular reciprocation of the plunger, from the regular variations of potential, and so of current and of magnetizing effect of the two solenoid coils. But, whereas the electrical resistance of the solenoid coils may be considered constant under all ordinary conditions (excepting the slight variations due to the heating effect of the current), the magnetic resistance or reluctance of the iron core is quite variable with the intensity of magnetization. So that while a regular variation of potential may produce a regular undulation of the current passing through the solenoid coils, the resultant effect upon the iron core plunger may vary within wide limits; also, according to the counter-electro-motive force, depending largely upon its speed of reciprocation, and its position in the field of force, which position may be more or less controlled by external mechanical forces.

* As in Van Depoele's double-acting pulsating current electro-magnetic reciprocating mechanism, for claims and applications of which see United States Patents, No. 422,855, of March 4, 1890; No. 458,873, of September 1, 1891; No. 461,294 and 461,295, of October 13, 1891.

The Two-coil Solenoid in these Experiments consisted of two coils, of 200 turns each, of No. 14, B. & S., double-cotton covered copper wire; both coils were wound in the same direction, on a thin brass tube, of 0·625 inch outside diameter, and 4·1 inch long; the coils themselves were each 1·9 inches long, and separated by a 0·1 inch fibre disk, and protected also at the outer ends by 0·1 inch fibre disks. The iron core forming the plunger was 0·5 in diameter, and 2·25 inches long, of soft, slightly annealed wrought iron, capable of carrying about 15,000 lines per square centimetre just below the point of saturation. The construction was not iron-clad. The pull was measured by a sensitive spring balance; and the plunger was nominally at rest when readings were taken—it being in static equilibrium under the action of the spring balance and the electro-magnetic stresses.

Preliminary Experiment; Potential Varied by Resistances, introduced in circuit with the solenoid coils, causing a variable current to be supplied to them, from a constant storage battery supply of twelve ampères and 1·75 volts. The inner ends of the solenoid coils connected to a movable or sliding contact along an adjustable resistance, and the outer ends connected to the outer terminals of this resistance, joining up the two solenoid coils as two parts of one coil, forming a differential coil-and-plunger traversed by a current of variable potential.

(*a*) Sliding contact dividing the adjustable resistances in the ratio of four to four (equally) between the two solenoid coils; maximum *downward* pull, three ounces.

(*b*) In the ratio of five (top solenoid) to three (bottom solenoid); 2·7 ounces.

(*c*) In the ratio of six (top) to two (bottom); 3·1 ounces.

(*d*) In the ratio of seven (top) to one (bottom); 3·3 ounces.

(*e*) In the ratio of eight (top) to zero (bottom solenoid coil cut out); 3·3 ounces.

The 2·25 inch plunger, under maximum downward pull, was almost invariably in one position, during this quarter-cycle of operations; its centre being about 1·725 inches above the centre line of the 0·1 inch fibre disk between the two coils; that is, a little more than half-way in the top coil.

The zero position of the centre of the plunger moved upward 0·95 inch—from 0·075 inch *below* the centre line of the fibre disk between the coils (for the four-to-four combination of adjustable resistances), to 0·875 inch *above* this line, when the bottom coil was cut out. This latter position should probably have been 0·95 inch (which is one-half the coil length of 1·9 inches), above the bottom of the top coil; that is, the plunger in normal position of equilibrium in one or the other coil alone, of about the same length, should be about central with that coil under all ordinary conditions. While, when both coils are equally energized the plunger is normally central between them, for thin separating disks, yet the two coils may be so far separated, longitudinally, that the zero position is more or less indeterminate. Other conditions being equal, the plunger not being exactly central between the two coils, shows that the external resistances introduced were not exactly equal in the four-to-four combination. Sylvanus P. Thompson speaks of the maximum pull of a single coil on a plunger of the *same length* of the coil, as occurring when the plunger is about half-way in; and of the differential action of the two coils in the above case, as being simply due to the difference between the ampère turns of the two separate coils.

Experiments with Rotating Brush Method of producing variation of potential and so of current in the solenoid coils. The diagram of connections is shown in *Fig. 1.* The dotted line connection, with voltmeter in circuit, shows the method by which the distribution of potential around the commutator was obtained, giving what Sylvanus P. Thompson has called the integrated curve of potentials. The ordinates of this curve (shown on line E of the plotted results) at any position of the rotating brush around the commutator, gives the total or integrated potential from the fixed brush terminal up to that point. The machine used in the experiment was a one horse-power motor, separately excited and run as a dynamo, at about 2,600 revolutions per minute (normal speed, 2,750). The equal resistances R' and R'' were introduced in the external circuit, which showed about forty-five volts and eight ampères when the rotating brush

was off the commutator. Owing to small variations in the speed of driving pulley, and slight unsteadiness of the exciting current supplied to the field coils, there were slight variations in the external circuit of the machine. The commutator had forty bars, and readings were taken with the rotating brush successively on each bar.

Two Sets of Experiments were made with this rotating brush combination:

(1) With the two coils of the solenoid operated as a differential coil-and-plunger, of which the results are plotted on *Sheet I.*

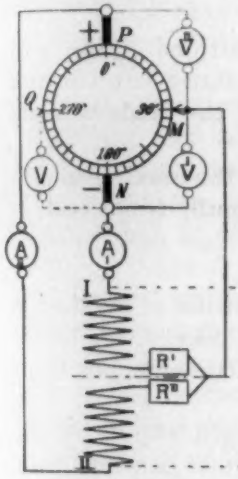


FIG. 1.

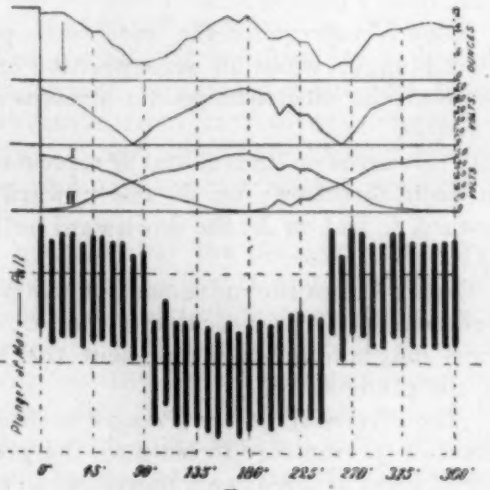


FIG. 2.

Diagram of connections, and successive positions of plunger.

(2) With the two coils operated as separate solenoids with opposing magnetic fields, of which the results are plotted on *Sheet II.*

The effective ampères, line *B*, and effective volts, line *D*, were obtained for the different points around the commutator by subtracting the corresponding ordinates of the curves on lines *A* and *C*, respectively. The portion of these curves *B* and *D*, on *Sheet I*, between 81° and 261°; and on *Sheet II*, between 72° and 270°—represent negative values, corresponding more or less to the variations of potential and

of ampère-turns chiefly effective in the bottom coil *II*, while the remaining portions of *B* and *D* represent the positive values, which are chiefly effective in the top coil *I*.

The curve on line *E* (the same on each sheet) represents simply the variations of the integrated curve of potentials, when there was no external circuit to the machine.

The curves on lines *F* and *G* represent the paths of the movement of the centre of the 2·25 inch plunger, under maximum pull—the former, *F*, when the maximum pull is upward from bottom coil *II* towards top coil *I*; and the latter, *G*, when the maximum pull is in the opposite direction, from *I* toward *II*.

Line *H* represents the successive positions of the 2·25 inch plunger when in zero position of static equilibrium between the electro-magnetic stresses of the fields of coils *I* and *II*.

The curves on lines *K* and *M* represent the maximum pull in each direction; on *K*, the upward pull, from coil *II* toward *I*; and on *M*, the downward pull, from coil *I* toward *II*.

Fig. 2 shows the movement of the position of maximum downward pull, as indicated on line *G*, of *Sheet I*, the heavy lines diagrammatically represent the successive positions of the plunger.

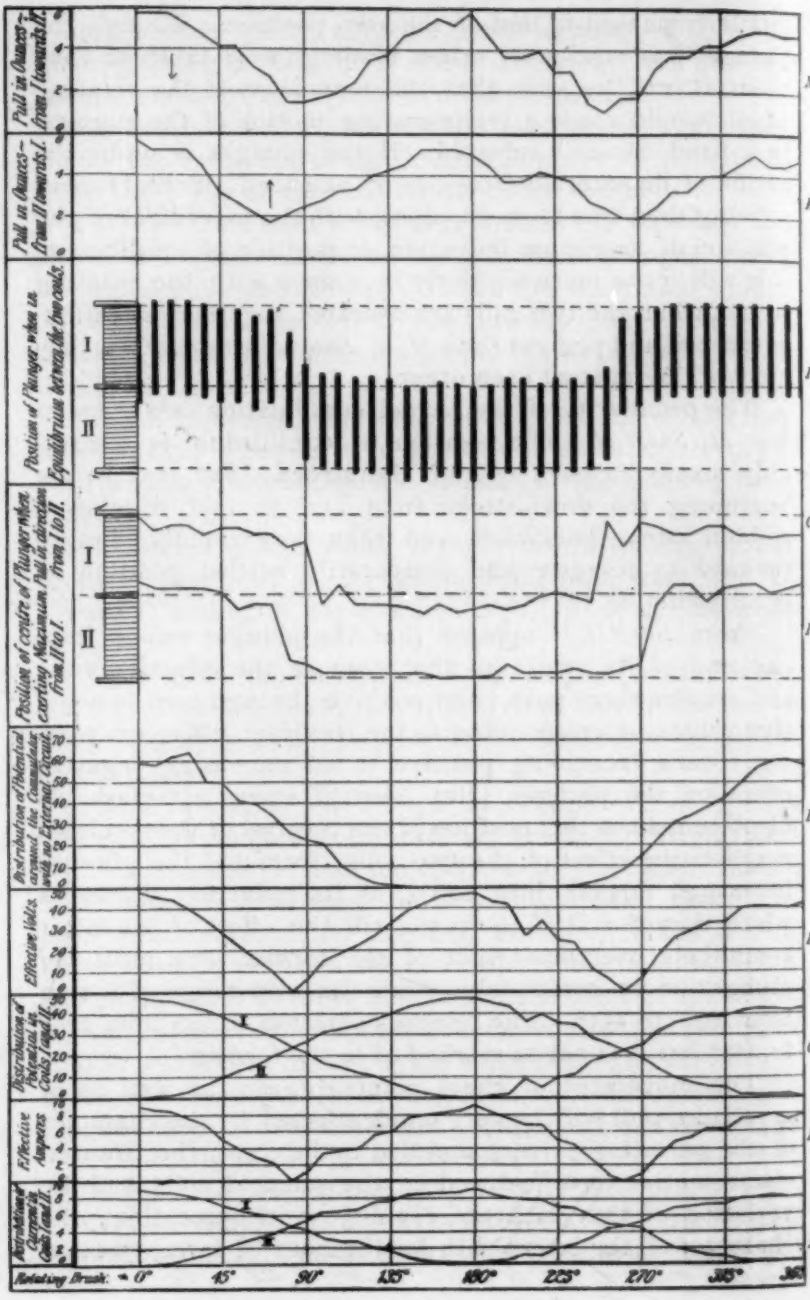
The Movement of the Plunger is brought about by the effort of its iron core to embrace the greatest possible number of lines of force; and, therefore, so to place itself that it shall have the maximum induction, and shall cause the least deformation of the magnetic circuits. When it is in a zero position between the two coils, it exerts no pull and has no tendency to move into one or the other of the coils; and, if external force is applied to move it out of this position, it will return unto it again when that external force is removed—coming back to rest, as it were, in a position of more or less stable equilibrium. This position falls within the two coils, as an interior position of zero pull; and between it and the exterior positions of zero pull of each coil, respectively, there occur the positions of maximum pull in each direction. These have also a movement, somewhat

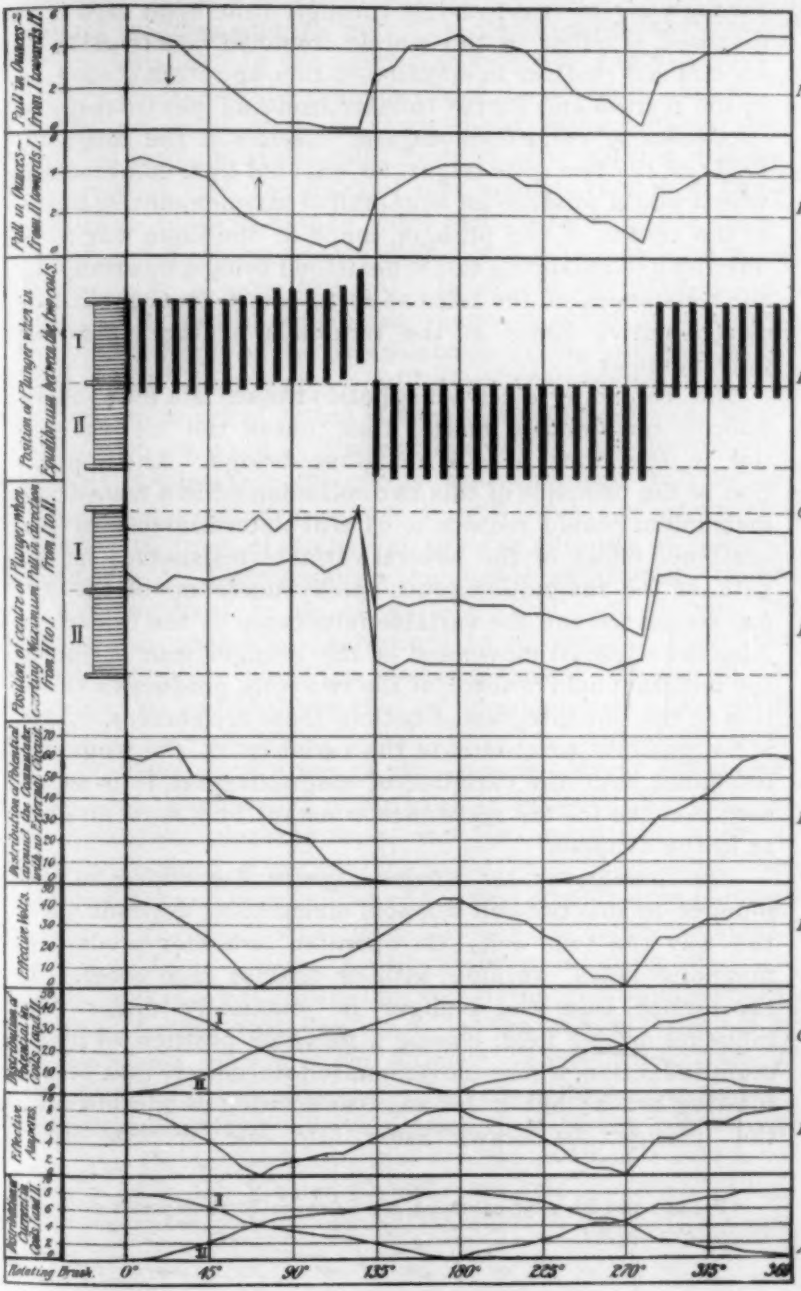
similarly phased to that of the zero position. Though the plunger was stationary when readings were taken at each point, it will be seen that the movement of the rotating brush would cause a reciprocating motion of the plunger in a fixed two-coil solenoid. If the plunger is under the action of no external forces, or of balanced external forces, —being then free to move, along with the movement of the position of maximum induction, or position of equilibrium, —it will move more regularly in unison with the rotating brush, when the two coils are operated together as a differential coil-and-plunger (line *H*, of *Sheet II*), than when they are working against each other.

The peculiarity of the second combination is shown on line *H*, *Sheet II*. The position of equilibrium is remarkably steady at each end of the stroke. But just before beginning the down-stroke, from 117° to 135°, it takes a sudden stroke backward, and then very rapidly plunges forward to its new and temporarily settled position of equilibrium, at 135°.

From *Sheet I*, it appears that the plunger passes from one end of its stroke to the other as the effective volts and ampère-turns pass from positive through zero to negative values—corresponding to the resultant induction passing from a decreasing positive to an increasing negative effect on the plunger. But *Sheet II* shows a remarkable displacement of this position of the reversal of the resultant magnetizing effect of the two coils; from 72° the plunger is pushed farther into coil *I*, as its induction decreases while that of coil *II* increases, till the effect of the latter completely overcomes that of the former, and pulls the plunger most completely within its own range of action from 126° to 135°. The reverse operation occurs from 279° to 288° but it is not so marked as in the former.

The movement of these points of zero as well as of maximum pull will be very much affected by the character of the pulsating current supplied to the coils; the counter-electromotive force induced in the solenoid coils, and the variation of this with the rapidity of reciprocation; the character of the return-path for the lines of force, whether


Pull in Ounces — from I towards II.
Pull in Ounces — from II towards I.
Position of Plunger when in Equilibrium between the two coils.
Position of centre of Plunger when exerting Maximum Pull in direction from II to I.
Distribution of Potential around the Commutator with no External Circuit.
Effective Volts.
Distribution of Potential at Coils Terminals.
Effective Amperes
Distribution of Current in Coils and E.F.
I
II
M
K
H
G
F
E
D
C
B
A
Rotating Brush: = 0° 45° 90° 135° 180° 225° 270° 315° 360°


Pull in Ounces from I towards II.
Pull in Ounces from II towards I.
Position of Plunger when in Equilibrium between the two coils
Position of centre of Plunger when carrying Maximum Pull in direction from I to II.
Distribution of Potential around the Commutator. Current zero.
Effective Volts.
Distribution of Current in Coil I.
Effective Amperes.
Distribution of Current in Coil II.
Rotating Brush.
0°
45°
90°
135°
180°
225°
270°
315°
360°
M
K
H
G
F
E
D
C
B
A
I
II

through air or iron; and, if through iron, upon how it is disposed, whether in the simple iron-clad construction of an external shell, or in addition to this an internal shell, as in the Ayrton and Perry* tubular iron-clad electro-magnet.

Balance of the Electro-magnetic Stresses of the magnetic fields of the two coils might be effected by a combination which would produce an equal fall of magnetomotive-forces at the centre of the plunger, much in the same way as is now done in balancing the Wheatstone bridge, by arranging the resistances of the arms so as to cause an equal fall of electro-motive forces at the terminals of the indicating galvanometer.

But balancing electro-magnetic stresses is a much more difficult and delicate matter than that of the fall of potential in the arms of a Wheatstone bridge. Any application of the principle of this two-coil solenoid in a measuring instrument would require a careful determination of the combined effect of the several variable resistances in the path of the magnetic circuit, chiefly made up of the air-gap resistance and the variable reluctance of the iron core. Also the slightest movement of the plunger into or out of the resultant field of force, of the two coils, produces a variation in the line-integrals of both of these resistances. As it is not possible to eliminate the variation of the magnetic resistance with the variation of magnetization, it is necessary to make the air resistance constant by a fixed air-gap, as in the dynamo.

The Stability of the Electro-magnetic Equilibrium of the plunger, in this two-coil solenoid mechanism, depends upon the way the two coils are operated, whether producing magnetic fields working with or against each other. In the former case the plunger is practically under the influence of one field, having a movable position of maximum induction, whose movement follows closely that of the rotating brush; but if for any one position of equilibrium, the plunger be drawn aside into one or the other

* For this and other typical forms, see Sylvanus P. Thompson's work on *The Electro-magnet.*

coil, and then released, it will slowly resume its former normal position of zero pull; the electro-magnetic equilibrium is stable. In the latter case, however, there is unstable equilibrium of the plunger under the action of opposing electro-magnetic stresses; for a slight movement of the plunger into one of the coils, from its zero position, will so far bring it into the field of maximum induction of that coil, as to cause it to take some new position, where it can best complete the magnetic circuit of that coil under whose influence it is now brought. In stable equilibrium, the plunger is wholly within the range of action of the one magnetic circuit of the two solenoids acting (differentially) as one coil. In unstable equilibrium, the plunger is partly within the range of action of each of the two opposing magnetic circuits, so that almost the slightest movement will send it rushing into the one or the other coil, in order to get into the position where it will have the maximum number of lines of induction passing through it. Moreover, line *H*, *Sheet I*, shows the stable equilibrium to be almost constant in its character; while that of *Sheet II* shows the unstable equilibrium to be variable, from the least instability when the electro-magnetic stresses differ most, at 0° and 180°—to that of greatest instability when these stresses are nearly equal, 45° to 135°, and about 270°.

Industrial Applications of this Two-coil Solenoid Mechanism vary with the character of the work to be done. For pumps, reciprocating machine tools, and like operations, where a steady forward or return stroke, or both, is required, the differential coil-and-plunger of the first combination is most useful. The electro-magnetic stresses are nearly constant, resulting from a more nearly uniform intensity of magnetization of the plunger core, and giving greater maximum pull with less variation than in the second case. For quick-return motion of the plunger, in machine-tool work, the rotating brush may easily be moved around more rapidly in one portion of its rotation than in the remaining portion, giving the plunger a definite ratio of advance to return, as in the Whitworth and other quick-return motions. For electro-magnetic forging, whether by a direct hammer

blow, or by the drop-forging process, riveting, rock drilling, and like operations requiring a definite hammer blow, the two coils may be connected up in opposition to each other, as in the second case. To develop greater power in the one stroke than the other, adjustable external resistances may be used, strengthening one magnetic field and weakening the other to suit the circumstances of the work; and in many cases diminishing the wear and tear on the machine due to the shock of the return stroke. But the loss of current caused by this arrangement may be obviated, by winding one or the other of the two coils in sections connected up in parallel,* so increasing the ampère-turns at either end to any desirable extent.

NOTE.—The author expresses to the following students in the Department of Electrical Engineering his many obligations for valuable assistance: Mr. F. McS. Thomas, for constructing the solenoid mechanism; Messrs. T. M. Brown, W. R. Molinard and J. B. Scott, for arranging the dynamo details; and Messrs. L. M. Aspinwall, H. W. Frye, H. Pattison, A. J. Rowland and R. I. Todd, for observations.

CORRESPONDENCE.

THE DYKE AT THE HEAD OF PEA PATCH ISLAND, DELAWARE RIVER.

To the Committee on Publications:

GENTLEMEN: With reference to the admirable lecture of Capt. F. A. Mahan, Corps of Engineers U. S. A., on "Philadelphia as a Seaport," published in your last issue, it may interest some of your readers to know that the dyke to be constructed at the head of Pea Patch Island above Fort Delaware, for the improvement of Bulkhead Shoal, is a departure from the dyke proposed for the same locality by the Board of Engineers of 1885, approved by the Chief of Engineers United States Army; and that the new dyke was proposed by the writer in April, 1890, while yet in the United States Engineer Office at Philadelphia.

The dyke proposed by the Board of Engineers was a curved dyke, presenting its concavity toward the Jersey shore, and its location with refer-

* The use of regulating resistances and of multiple-sectioned coils in this mechanism are set forth in the United States Patent (Van Depoele), No 422,855, of March 4, 1890.

ence to the currents was, in the opinion of the writer, not well calculated to produce the desired effect upon the shoal.

When Major C. W. Raymond, Corps of Engineers, took charge of the office in Philadelphia, in the spring of 1890, the assistant engineer, Mr. L. Y. Schermerhorn, brought before the writer the question of the improvement of Bulkhead Shoal, and in the discussion which ensued, the writer, with the light of his several years of observations and studies of the behavior of tidal currents on the Delaware River, in which he had been exclusively engaged, demonstrated the inefficiency of the dyke proposed by the Board and expounded the project of the new dyke, known as the west dyke, which Capt. Mahan ably and succinctly describes in his lecture as a dyke "to begin at the head of Pea Patch Island and extend up stream. Its middle and lower parts are intended to train the flood currents on the bar and prevent the westward movement of the flood channel, while the upper is to catch part of the ebb down the Delaware channel."

This dyke is also a curved dyke, but instead of presenting its concavity toward the Jersey shore, presents it toward the Delaware shore with the important features described by Capt. Mahan.

As soon as the assistant engineer, Mr. Schermerhorn, became converted to the new dyke, he took it upon himself to convert Major Raymond, who at first opposed it and finally became enamored of it to the extent of meeting the natural opposition of the Board of Engineers. It was at this time that the writer was suddenly notified that his services for reasons of economy would have to be dispensed with, and was given about one month and a half to leave. He left, however, one month sooner, with loss of his salary and not a word on official record about the whole matter.

Mr. Raymond succeeded, in his turn, in convincing the Board of Engineers of the superiority and merits of the new dyke he had espoused, and received the approval of his chief.

There has been before this no occasion given to put the above facts on record, and the writer is glad to do it now before the new dyke is pronounced either a success or failure.

L. d'AURIA.

BOOK NOTICES.

Electricity and its Recent Applications. Edward Trevert. Bubier Publishing Company, Lynn, Mass.

This is the fifth book upon electrical subjects by this author, and as his style is so well known it need not be referred to again. A great many books have recently appeared, purporting to disclose the mysteries of electrical phenomena to the youthful and ignorant, and to tell them how to make and use dynamos, motors, batteries and sundry apparatus. Doubtless such books have a field, and this latest one is simply another addition to the number. It is very easy reading, not requiring much thought, except where it is impossible for the subject-matter to be made intelligible to beginners anyway,

and in fact it does not attempt to elucidate *principles* at all, but to explain ephemeral apparatus so that, without much effort, the reader can get a smattering familiarity with some of the most prominent applications of electricity, and be told how to make some pieces of apparatus and perform some experiments.

The book opens with the misleading statement that "electricity and magnetism are very closely related, electricity producing magnetism, and magnetism producing electricity." Being coëxistent they can hardly be said to produce each other. A few pages of dissertation follow upon some experiments with magnets and iron filings, although the reader is left almost entirely in the dark as to the principles involved, and yet without further elucidation he is required to read under the chapter "Field Magnets" about "magnetic fields," "electro-magnets," "to vary the intensity of magnets," etc., and is expected to understand what he is reading, and to understand the various forms of field magnets which are shown with but slight reference; after which some attempted explanations are given about the design of magnets and armatures! How beginners are to understand the design of magnets and armatures without having been given the first principles, it is difficult to perceive. So also in the first chapter, after a few remarks about the time-honored amber experiment, the reader is at once confronted with the complicated Holtz and Toeppler machines, which are again erroneously called "frictional machines" and which scarcely one reader in 1,000 will understand. Yet six pages are devoted to it in this book for amateurs and beginners.

The second chapter is devoted to "Voltaic Batteries" and with but a feeble introductory explanation of the action of cells, some of the more modern cells are explained and directions given for constructing them and for setting them up, although most of this is put into the chapter on "Gas Lighting Apparatus."

In the brief discussion of "storage batteries" the reader is impressed with "the possibility of *storing electricity!!*" And no attempt is made to set him right. The terms "current," "resistance," "ampères," "ohms," "volts," etc., are used freely in this chapter though no explanation is given of what these terms mean; some calculations of the number of cells required to run a lamp are given, though the reader has not even been told of the relation existing between the quantities involved.

And so all through the book there occur some explanations of apparatus, but no attempt at a logical presentation of fundamental principles, but on the contrary many misleading statements and obsolete definitions.

The volume closes with an "illustrated dictionary of electrical terms and phrases" of twelve pages and seven illustrations; many of the definitions contained in it are unfortunately as unintelligible and perplexing as the following: "Potential: Power to do work;" "Condenser: An apparatus for collecting and holding electricity;" "Electrode: A pole of a battery;" "Pole: The pole of a battery is one of its terminals;" "Terminal: The point at which the electricity enters or leaves an electrical apparatus," thereby informing the reader who wishes to know what an electrode is, that it is "the

point at which electricity enters or leaves an electrical apparatus." Yet in the preface is found the statement that "there seems to be a demand for more information * * * particularly among amateurs and students. For this reason I add this one to the list * * * and confined myself to facts, rather than theory."!!

Many excellent pictures of some modern commercial apparatus, mostly from trade publications, are shown, which serve their purpose well in interesting the amateur reader who does not see the electrical journals, but many of the illustrations are merely photo-engravings of extremely bad sketches, for instance those on pp. 178, 180, 185, and others, and it is surprising that such bad ones were ever permitted to appear in print.

There is no index to the book and no pages given in the contents, neither is there the slightest intimation at the top of the page, of the subject of the chapter, so that the reader is obliged to look from page to page should he wish to find a certain chapter, or look up a certain subject. It is most extraordinary how careless and regardless of the convenience of readers some authors and publishers are in matters of this kind.

For anyone wishing to read a little descriptive matter about batteries, dynamos, lamps, etc., and how to put up and operate electric bells and gas-lighting apparatus, and to make dynamos or motors, this book may prove useful, but for those seeking explanation of principles, and of the terms and quantities involved, it will be utterly useless.

It is to be regretted that so many so-called "practical" or "amateur" treatises make the serious mistake of not adopting the very first essential principles of education in the methods of presenting a subject, dealing as they purpose doing, with amateurs and persons of little education. They are not to be criticised for endeavoring to enlighten the unenlightened; that is a worthy object, but they do not put their readers on any solid foundation, but turn them loose among kaleidoscopic views of machines and appliances and alluring temptations of making dynamos, motors, etc., yielding to which generally ends in disappointment, and also allow them to form the most erroneous notions about the simplest phenomena. H. S. H.

Duhem, chargé d'un cours complémentaire de Physique mathématique et de Cristallographie à la Faculté des Sciences de Lille. *Leçons sur l'Électricité et le Magnétisme*. 3 volumes grand in-8, avec figures dans le texte, se vendant séparément. Paris: Gauthier-Villars et fils. 1891. Tome I: Conducteurs à l'état permanent. 1891. 16 fr.

The aim of the author of this work, as stated in the preface, has been to assemble in definite form and logical sequence the results of almost a century of mathematical investigation of the laws of electricity and magnetism, carried on by the leading specialists of all countries.

The first part of the present volume is devoted to a study of the fundamental laws of the electrical equilibrium and of the best mathematical methods of dealing with the phenomena of electro-statics. Beginning with the laws of Dufay and Coulomb, the properties of potential at points

external and internal to a given system are taken up, together with the laws governing surface charges in masses of different size and form.

Part 2 contains much of value regarding the distribution of electricity in conducting bodies, with ample mathematical treatment of the laws of equilibrium. In Chapter 5 the Dirichlet principle and the so-called problems of Le jeune Dirichlet are given interesting treatment. It is shown that the problems are really but another form of a problem proposed by Green, in 1828. In 1839, Gauss also stated an equivalent problem, and in 1845, Sir W. Thomson stated still another form of the problem, showing by a method analogous to that of Gauss that it was always capable of one solution. The scope of the Dirichlet principle is shown and the weak points of Le jeune Dirichlet's demonstration indicated in a forcible manner. In logical order we find the laws of the natural distribution of electricity on a conducting body, with an exposition of the elegant method of M. G. Robin for determining the same.

The third part consists of experimental studies of electrical distribution, examples of various cases of electrical influence and special classes of condensers being given with their complete treatment. Green's problem with solutions by his own method and that of Gauss, with Dirichlet's application, are taken up in Chapter 5 along with the theorems of Faraday and their applications to questions of electrical influence.

Part 4 takes up thermodynamics, showing certain theorems forming a bond between this branch and mechanics. Book 10 treats of the fundamental laws of electrical equilibrium in metallic conductors, *i. e.*, in a system composed of conductors in which the electrical distribution can be modified without modifying the physical or chemical state of any one of them. Chapter 4 takes up the law of Ohm, and is followed by the proof of this law in conductors of special forms. The interesting geometrical treatment given shows as its result the absolute solution of the movement of electric currents in conductors of the form of a plate, knife section, curved knife section, etc. The law of Joule is stated with a great number of hypotheses in connection therewith. The electrical equilibrium in a conductor composed of different metals is shown as affected by the laws of thermodynamics. The Peltier effect is studied in Chapter 8, and in the two remaining chapters the conditions under which thermo-electric currents are produced are considered together with the Thomson effect.

The final book of the volume is given up to electrolytes with the laws of Faraday. The distinction between chemical and voltaic heat is shown with the relation established by M. von Helmholtz between the two and the electromotive force of a hydro-electric battery.

The work, as a whole, cannot be regarded as a compendium of theories, but rather as a treatise on the theories of electricity and magnetism. The author realizes the demand that exists in this as in other branches of the science, namely, for text books which shall embrace under one cover the results of the study and experiment of the leading philosophers of all countries, and to meet it has collected all available matter from reviews, scientific papers and works published in all languages. Having arranged his subjects

in logical order he has crystallized upon this framework the ideas that seemed most prolific and desirable.

The author has made a novel and daring departure for the usual methods of treating the theoretical study of the phenomena of the science. He borrows from "Mechanics" and "Thermodynamics" certain well-proven principles and theorems, and about these groups all the important and prolific theories of electricity. While these principles, as ordinarily evolved, are sufficient to meet the problems of physics, it is necessary to surround them by so many restrictions, conditions and hypotheses to meet the complex cases offered by electric theories, that the undertaking is a serious one.

The writer has therefore chosen a new course, and instead of first showing, as would logically be necessary, the manner in which these principles may be used to classify the theories to be studied, he shows the bond as the study proceeds.

The definitions given are original and clear without being lengthy. The nomenclature adopted is supported by good reasons, and is not to suit the author's convenience or fancy. The mathematical methods are satisfactory, complete and logical.

The treatment of metallic conductors, both homogeneous and heterogeneous, with the application of the laws of the thermodynamics to these conductors, is very complete, and undoubtedly the most extensive and thorough up to date.

The chapters upon electrolytes are rather brief, although they cover many useful propositions relating to open and closed circuit batteries both polarizable and non-polarizable. If one considers, however, to what extent they would lead were the same methods employed as for metallic conductors, this is not surprising.

No attempt is made to introduce any of the usual matter relating to the measurement of current strength, etc., nor anything regarding the instruments used. The work is not, in fact, calculated for the use of the practical or experimental electrical engineer as a manual, but rather as a treatise which shall show the bonds uniting the various electrical theories, and the scope and extent of these theories. C. J. R.

A Manual of Mining. By M. C. Ihlseng, C.E., E.M., Ph.D. Pp. 428. 8vo. Cloth, $4. New York: John Wiley & Sons.

This is, we believe, the first work of the kind published in this country, and as the literature of mining in the English language is singularly scant, it makes a most welcome addition.

As a text-book on the art of mining it does not compare favorably with the German works of Serlo, Köhler, or even with the French of Callon.

The author has unfortunately attempted to cover too much in a small volume, and as a consequence many of the most important parts of his subject are treated in a superficial manner; indeed, this is so far true that unless the reader has had some experience in mining, the book would not be entirely intelligible. The book is unevenly written, some of the chapters

being better than others. Those on ventilation, it should be said, are particularly good. The author states in the preface "the work is designed as an elementary treatise for the use of those desiring a reference book." The book does not conform to this description, for the reader is met at every turn with terms and expressions which would require considerable previous knowledge of mining on his part to be intelligible.

On the whole the book is a good one. It contains much valuable practical information and, therefore, forms a valuable contribution to the literature of the subject. It is to be regretted that it is not better written; the author's style is often involved, rendering his meaning obscure; his English lacks clearness, and the interjection of the slang of the mining districts of our far West, cannot be considered as good form in a work of this character.

F. L. G.

PHOTOGRAPHIC NOVELTIES.

[*Abstract of remarks of Mr. John Carbutt, made at the stated meeting of the Institute, Feb. 17, 1892.*]

Mr. John Carbutt exhibited several large and beautiful photographs of scenery on the Pennsylvania Railroad, taken on his celluloid orthochromatic films, and spoke of the advance in use of that material, as follows:

Mr. President and Members:

It will be remembered by members of the Institute that some four years since I read a paper on celluloid as the new substitute for glass in photography, and that, although the sheets of celluloid measured 20 x 48 inches, the largest negative made at that time was 8 x 10 inches. Since that time the use of that material both by amateur and professional photographers has greatly increased, as also the size of negatives made, especially by the professional photographers, notably Mr. W. H. Rau, of this city, who, during the past summer, has made negatives of views on the line of the Pennsylvania Railroad of the size 18 x 22 inches, used flat in the regular plate-holder, and 18 x 48 inches used in the panoramic camera, but bent to a half-circle, as shown by the sketch on the blackboard.

Here is one of the flexible holders carrying the 18 x 48 celluloid film, which as you see can be bent to a half-circle, which form it occupies when attached to the camera, the back of which forms a half-circle, the front being flat and flexible, allowing the lens to be rotated from side to side while making the exposure. The lens used has a focus of fifteen inches, and the negative includes an angle of 165°; whereas if it was possible for a lens of fifteen inches focus to cover a flat surface of forty-eight inches, the angle would only be 110°.

The photographs here for your examination fully illustrate how perfectly the celluloid answers the purpose to hold the sensitive film, doing away with both weight and risk of breakage to which glass is subject. One of our leading amateurs, Dr. Chas. L. Mitchell, made over 500 8 x 10 nega-

tives of Norway the past summer on orthochromatic films, and the use of celluloid films is greatly on the increase by travellers, tourists, and the professional photographer.

The second advance in photography to which I desire to call your attention, relates to the production of a lens capable of giving a greatly magnified image of an object at a great distance from the camera, and is called the photo-tele objective. Dr. Miethe, of Berlin, and Mr. T. R. Dallmyer, of London, both claim originality in the construction of the lens, but it appears both were anticipated several years, for in the *British Journal of Photography*, of January 29th, this year, Dr. Hugo Schroeder gives dates and drawings of a photo-tele objective constructed by him in 1869-70, and I have in my possession the amplifier constructed in 1869, by the late Mr. Joseph Zentmayer, for Prof. Henry Morton, and attached to the telescope used in taking photographs of the eclipse of 1869. The sun's direct image was thus made about two and one-half inches in diameter. To Dr. Miethe, however, is due the credit of first constructing an objective suited to the photographer's use, and I will now show on the screen, first a view made with the ordinary objective, and then one by the new. Now I will throw on the screen a slide of both pictures; you readily see the immense difference in the size of the same object, both cameras being placed side by side, and of about same focal length. You will observe the sign on the building, taken by the Miethe objective is about ten times larger than the one with regular photo lens.

[By courtesy of the *American Journal of Photography*, the *Journal* is enabled to exhibit to its readers the accompanying handsome Ives' process plate of the pictures referred to by Mr. Carbutt.—W.]

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, March 16, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 16, 1892.

Mr. JOS. M. WILSON, President, in the chair.

Present, 103 members and seven visitors.

Additions to membership since last report, nine.

The Secretary reported the resignations of Messrs. Wm. Harkness, Jr., and John F. Haskins from the Committee on Science and the Arts. The vacancies were filled by the election of Mr. Arthur Kitson for the unexpired term of Mr. Harkness, and Mr. J. C. Trautwine, Jr., for the unexpired term of Mr. Haskins.

Mr. F. Lynwood Garrison, who had been named as the Institute's representative, to witness the recent tests of armor plate made at the Indian Head proving grounds, under the direction of the Ordnance Department of

the Navy, gave a description of the character of these tests, and of the conclusions to be drawn therefrom, illustrating his remarks by the exhibition of a series of lantern slides. (A report on this subject will shortly appear in the *Journal*.)

Mr. Elmer G. Willyoung described an extensive and handsome series of philosophical and engineering instruments made by Queen & Co., of Philadelphia, in the construction of which aluminum is employed largely. Mr. Willyoung explained that as the result of long-continued experiments, these manufacturers had succeeded in overcoming most of the difficulties in the way of working and manipulating aluminum. The exhibit was much admired, and the speaker's remarks evoked a number of inquiries.

Mr. H. W. Bartol described and illustrated by a series of lantern slides the construction of the Buda Pesth electric railway, and gave an account of its principal features—technical and economic. (A description of this railway appears in the *Journal* for February, 1892.)

Mr. John H. Cooper presented an abstract of the report of the Committee on Science and the Arts, on the Batchellor compound locomotive, manufactured by the Rhode Island Locomotive Works, of Providence, R. I., with suitable illustrations.

Mr. John Carbutt presented some remarks in relation to the admirable results achieved by Mr. Fred. E. Ives, in the field of color photography, which, in his judgment, so far as practical results were concerned, were far in advance of anything that had as yet been accomplished elsewhere. He urged that it was eminently fitting for the Institute to recognize the value of the work of one of its own members, and moved that the subject of Mr. Ives' investigations and results in the field of color photography be referred to the Committee on Science and the Arts for investigation and appropriate recognition. The motion was carried.

The Secretary offered the following resolution, which was adopted unanimously :

Resolved, That the grateful thanks of the Institute be and are hereby tendered to Mr. Fred. E. Ives, in appreciation of the zealous and gratuitous services rendered by him during a series of years in superintending the work of lantern illustrations at the meetings and lectures, which he has done with exceptional skill and ability.

Adjourned.

WM. H. WAHL, *Secretary*.